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Transfer of Stimulus Control across Instrumental Responses is attenuated by Extinction in Human Instrumental Conditioning

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Abstract

Transfer of behavioral control by a discriminative stimulus (S^D) between different instrumental responses trained with the same outcome has been consistently observed in nonhuman animals, regardless of whether the discriminative stimulus and the instrumental response have undergone extinction. Based on this result, it has been proposed that extinction of nonhuman instrumental learning does not affect S^D-outcome associations. Two experiments explored whether this was the case in human instrumental conditioning. Both experiments used a video-game task where participants pressed different colored keys to defend Andalusia from the attack of ships and planes. Key-pressing was reinforced with the destruction of the ship or plane. In Experiment 1 removing the response-contingent outcome extinguished the instrumental response, while responding to a non-extinguished response remained high. As in the animal literature, Experiment 2 found positive transfer of an S^D between different responses that produce the same outcome, suggesting the formation of a S^D-outcome association in human instrumental conditioning. Contrary to what has been found with nonhuman animals, extinction of the response in the presence of the S^D eliminated the transfer effect, suggesting that the S^D-outcome association is deteriorated in human instrumental extinction.
Key-words: Human instrumental conditioning; extinction, contents of learning, transfer test.

Resumen

La transferencia en el control de estímulos en la respuesta instrumental es atenuada por la extinción en el condicionamiento instrumental humano. En animales no humanos se ha encontrado consistentemente la transferencia de control conductual entre un estímulo discriminativo (E^D) que ha sido entrenado con una respuesta instrumental concreta y una respuesta diferente que comparte la misma consecuencia, independientemente de si se ha extinguido el estímulo discriminativo y la respuesta instrumental. De acuerdo con este resultado, se ha propuesto que la extinción del aprendizaje instrumental no afecta a la asociación E^D-consecuencia en animales no humanos. Se realizaron dos experimentos con el objetivo de explorar la extinción en el condicionamiento instrumental humano. En ambos experimentos se utilizó una tarea que simulaba un videojuego en el que los estudiantes debían presionar distintas teclas de colores para defender Andalucía del ataque de barcos y aviones. El experimento 1 encontró que la omisión de la consecuencia de una respuesta

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producía su extinción, mientras permanecía alta la respuesta en una alternativa de respuesta que no había sido extinguida. El experimento 2 encontró una transferencia positiva entre un E^D y una respuesta instrumental que había compartido la consecuencia con la respuesta que fue entrenada con el E^D, sugiriendo que una de las asociaciones que se forman en el condicionamiento instrumental humano es la asociación E^D-consecuencia. En contra de lo que se ha encontrado en la literatura con animales no humanos, la extinción eliminó el efecto de transferencia, sugiriendo que la extinción deteriora la asociación E^D-consecuencia en el aprendizaje instrumental humano.
Palabras clave: condicionamiento instrumental humano, extinción, contenidos del aprendizaje, prueba de transferencia.

An important part of the analysis of human learning in the last quarter of the past century has focused on the study of causal learning from a stochastic point of view. That is, much of the work has dealt with analysis of the rules that people use to determine that two events correlate or cause each other (see Perales, Catena, Ramos, & Maldonado, 1999, for a review). Rule-based perspectives were challenged by a number of authors, most of them animal learning researchers, who applied the same associative principles used for explaining animal learning to the study of human causal learning (e.g., Dickinson & Shanks, 1996; Shanks, 1993; Wasserman, 1993; see also Miller & Matute, 1996b). Much of the subsequent work in human learning has been to contrast these two classes of learning explanations, rule-based and association-based theories (e.g., Catena, Maldonado y Cándido, 1998; Kao & Wasserman, 1993; Levin, Wasserman & Kao, 1993; Maldonado, Catena, Cándido & García, 1999).

Part of the research developed to confront these two approaches to human learning has been conducted with instrumental tasks, providing extraordinary advances in the knowledge of the conditions and the mechanisms of human instrumental learning (see Shanks, 1993, for a review). However, to our knowledge, only one study has been focused on the analysis of the contents of human instrumental learning (Vega, Vila, & Rosas, 2004) and no study has been conducted to explore the contents of extinction.

By the contents of instrumental learning, we refer to the idea that different associations may be established among the three elements involved in an instrumental learning situation: the discriminative stimulus (S^D), the instrumental response (R), and the outcome (O). Some have considered that the associative structure underlying instrumental learning is an association between the instrumental response and the outcome –R-O association (e.g., Tolman, 1932). Exploring this idea, Colwill and Rescorla (1985) trained rats to performe two instrumental responses where each was followed by two different outcomes (food pellets and sucrose). The motivational value of one of the outcomes was then devaluated by pairing it with LiCl. This devaluation led to a reduction in the response that had led to the now devalued outcome, suggesting that animals established a R-O relationship during the initial training.

More recently, Vega *et al.* (2004) found similar results in human participants. In a videogame situation, two different responses (pressing colored keys in a computer keyboard) were followed by two different outcomes (activation of two different weapons, torpedoes or missiles) in the presence of two different discriminative stimuli (a ship or a plane). Outcome devaluation was conducted by indicating participants that one of the weapons was not operative any more. Outcome inflation was conducted by indicating participants that one of the weapons was more powerful now so that it could destroy any attacker. Each of these treatments selectively increased or decreased the response that had been paired with the outcome, suggesting that participants had established R-O associations during the instrumental training.

However, the outcome devaluation effect found in those studies was not complete. Though devaluing the reinforcer reduced the response rate in the behavior that was originally followed by that reinforcer, the loss of responding was not complete, suggesting that other associations may contribute to instrumental performance. The association between the discriminative stimulus and the response –S^D-R (e.g., Thorndike, 1932); the relationship between the discriminative stimulus and the outcome –S^D-O (e.g., Colwill and Rescorla, 1986; Hull, 1930); and the hierarchical association between the discriminative stimulus, the response and the outcome –S^D[R-O] (e.g., Rescorla, 1985) could all be contributors. Evidence of all of the above associations as contributors to instrumental performance has been reported in nonhuman animal's literature (e.g., Colwill, 1994).

Other than the outcome devaluation procedure, one useful technique developed to study the contents of the instrumental learning has been the transfer technique. Colwill and Rescorla (1988) used this procedure to evaluate the S^D-O association in animal instrumental learning. They trained rats to perform an instrumental response to obtain sucrose in the presence of a discriminative stimulus, while reinforcing a different response with pellets in the presence of a different discriminative stimulus. Subsequently, rats were trained with two new responses, one reinforced with sucrose and the other reinforced with pellets. Finally, the animals were tested in extinction in the presence of the two discriminative stimuli with the two responses that were never paired with them. Each discriminative stimulus specifically facilitated the response with which it shared the outcome. These results support the establishing of a S^D-O association during the original training. Paredes-Olay, Abad, Gámez, and Rosas (2002) have obtained similar results in human predictive learning.

The outcome devaluation and transfer techniques have proved to be useful to evaluate the associations established in animal instrumental extinction. The instrumental extinction procedure simply involves no longer following the instrumental response with the reinforcing outcome. This procedure produces a clear extinction effect shown as a decrease in the response rate (e.g., Rescorla, 1992, 1993b). The simplest candidate to explain the extinction effect is the assumption that extinction erases the associations established during acquisition (e.g., Estes, 1950; Rescorla & Wagner, 1972), an assumption that it is shared by many neural network models (e.g., McCloskey & Cohen, 1989).

A large body of evidence showing that the response can be recovered without explicit re-training, both in nonhuman and human animals, challenges such an explanation. The simple passage of time after extinction produces spontaneous recovery of the extinguished response (e.g., Pavlov, 1927; Rescorla, 1996; Vila & Rosas, 2001). Similarly, a context change after extinction produces renewal of the extinguished response (e.g., Bouton & Bolles, 1979a; Rosas, Vila, Lugo, & López, 2001). And adding a new neutral stimulus at the time of testing produces a recovery of the extinguished response (i.e., disinhibition, Pavlov, 1927). The presentation of the outcome before the test reinstates the extinguished response (e.g., Bouton & Bolles, 1979b; García-Gutiérrez & Rosas, 2003). These phenomena suggest that the associations established during acquisition are not erased, but inhibited by the new learning that takes place during extinction.

Prompted by the preceding results, different theorists have proposed that extinction leads to the establishment of stimulus-no outcome or response-no outcome associations in classical and instrumental learning, respectively. These associations are assumed to coexist with the "excitatory" associations between the stimulus or the response and the outcome established during the acquisition training (e.g., Bouton, 1993; Konorski, 1948).

According to this idea, Rescorla (1993b) showed persistence of the R-O association after extinction. Using the reinforcer devaluation procedure, Rescorla (1993b) found that devaluation produced a selective depression of the response that had been paired with the devaluated outcome, regardless of whether that response had been extinguished or not (see also Colwill & Rescorla, 1985). Such a result suggests that the association between the response and the outcome remains active after extinction.

Given that response-outcome associations do not seem to be affected by extinction, the question of what is learned during extinction remains open. One possibility is that a S^D-NoO association is learned that eliminates the motivation to respond, even in the presence of the R-O association. This possibility has been supported by the use of the transfer technique that we described above (Colwill & Rescorla, 1988). Rescorla (1992) trained rats with two instrumental responses, one followed by sucrose, and the other followed by food pellets. Following this training, a third response was followed by sucrose or by food pellets depending on whether the S^D was a light or a tone. After extinguishing the third response in the presence of one of those discriminative stimuli, the final test was conducted with the two original responses in the presence of the discriminative stimuli. Regardless of whether the discriminative stimulus was extinguished, it elevated response rate in the alternative with which it shared the outcome. According to these results, extinction did not affect the association between the S^D and the outcome (see Delamater, 1996 for similar results in classical conditioning).

The results of these experiments do not support the establishment of R-NoO or S^D-NoO associations during extinction (e.g., Rescorla, 1991, 1993b). If extinction would prompt such associations, neither the devaluation effect nor the transfer effect should be found after extinction. Recent results seem to suggest that the extinction treatment leads to the formation of an inhibitory association between the discriminative stimulus and the response the subject is performing during extinction (e.g., Colwill 1991, 1993; Rescorla, 1993a; see Hull, 1943). However, the evidence of this association provided by those studies is indirect, and the question of what is learned during extinction remains open.

To our knowledge, there are no studies to explicitly address the contents of extinction learning in human instrumental conditioning. The first goal of the present experiments was to design a technique that would allow for the study of instrumental extinction in humans. The technique we developed was based in the video game presented by Paredes-Olay *et al.* (2002) to study the contents of human predictive learning. In the game, participants had to defend Andalusia from attacks by ships or planes by pressing keys in a standard computer keyboard. Destruction of the planes and ships were used as two different outcomes. Discriminative stimuli were colored shapes in the top of the screen. Experiment 1 was conducted to assess our technique in conditioning and extinguishing the instrumental responses. Experiment 2 was conducted to assess whether an S^D-Outcome relationship could be established with our technique, and whether this relationship was affected by extinction of one of the responses in the presence of its discriminative stimulus.

Experiment 1

This experiment was conducted to assess our technique in the acquisition and extinction of instrumental learning in humans. The design of this experiment is presented in Table 1. In an adaptation of the technique developed by Paredes-Olay *et al.* (2002) described above, two instrumental responses (pressing one key or another counterbalanced as R1 and R2) were reinforced with two different outcomes (destruction of the ship or plane, counterbalanced as O1 and O2) in the presence of two different discriminative stimuli (A and B). Acquisition would appear as an increase in the rate of responding to the appropriate response alternative in the presence of the discriminative stimulus.

Subsequently, one of the responses was extinguished in the presence of its discriminative stimulus (i.e., A: R1-No O) while the other stimulus was not presented. In the final test, the rate of responding in the non-extinguished and extinguished responses was tested in the presence of their respective discriminative stimuli. Extinction should be shown as a lower rate of responding in the extinguished response than in the non-extinguished response.

Method

Participants

Participants were 8 undergraduate students from the University of Jaén between 18 and 26 years, naive to the task, and they received course credit for participation. Approximately 75% were women and 25% were men.

Apparatus

Participants were run individually in three adjacent isolated cubicles. Each cubicle had an IBM compatible personal computer with which the task was presented. The

Table 1. Design of Experiment 1.

Response training	Discrimination Training	Extinction	Test
R1-O1 R2-O2	A: R1-O1 B: R2-O2	A: R1- or B: R2-	A: R1- B: R2-

procedure was implemented using the program SuperLab Pro (Cedrus Corporation).

Discriminative stimuli were a red rectangle and a blue oval, both with the sentence "Warning, 500 meters" inside them, counterbalanced as A and B. Keys F and J were covered with green and orange stickers and were counterbalanced as instrumental responses R1 and R2. Plane and ship destruction were counterbalanced as outcomes O1 and O2.

Procedure

Participants entered their cubicles and sat in front of the computer. The following instructions were presented in Spanish in successive screens (800x600 pixels). Instructions were presented using a white Times New Roman 18 bold font against a black background. Participants had to press the B key to advance in the instruction screens. The following screen was presented before beginning with the specific instructions of the experiment:

> "Before starting with the experiment we would like to thank your presence here, because without your collaboration this research could not be conducted. You should know that the task that you are about to do does not have good or bad responses. We are interested in studying basic mechanisms that appear in all the people. If you wish to participate in the experiment, we would ask to do so with your best motivation. You do not need to identify yourself. Your data will be pooled with the data from the rest of the group, and your results will be absolutely anonymous. Once the task is finished, if you would like to know what it was about, please ask the experimenter. If you do not wish to continue, you may leave the cubicle now. Otherwise, please press the B key".

Response training. This phase began with the following instructions:

> "(Screen 1). Welcome! Andalusia is being attacked by sea and air. Your work will be to defend Andalusia by pressing the ORANGE and GREEN keys. One of the keys fires anti-aircraft missiles, whereas the other one fires anti-boats torpedoes. Your mission consists of destroying the ships and the planes before they reach the Andalusia's coast. (Screen 2) The computer screen is the control console of your Center of Defense. You will be able to see the attacking planes and ships that will appear in different monitors. Ships and planes have protective shields that enable them to resist your attack, so sometimes you will need to shoot several times to destroy them. In some occasions, your enemies will escape before you are able to destroy them. (Screen 3). The battle begins. Remember, one key ONLY destroys SHIPS and the other one ONLY destroys PLANES. If you have any doubts, consult the experimenter now. Otherwise, hit the B key to begin. Good luck!"

Five R1-O1, and 5 R-O2 trials were presented randomly intermixed. In those trials either the plane or the ship appeared in one of the monitors within the screen. Correct responses were reinforced under a variable interval reinforcement schedule with a mean of 2 sec. and a range between 1 and 3 sec. Each trial lasted 4 sec.

Discriminative training. The following instructions preceded the beginning of the phase:

"(Screen 1) Congratulations! You already know which key activates the weapon that destroys the ship, and which one destroys the planes. Now ships and planes will ATTACK TOGETHER. Your weapons have a reaching range of 500 meters. You will not be able to destroy the enemies that are beyond that range. (Screen 2) However, in the console of your Center of Defense (the computer screen) a symbol will appear that will indicate whether any of your enemies (ship or plane) is closer than 500 meters, so that it can be destroyed. (Screen 3) It is important to know that only one of the attackers is closer than 500 meters at a given time, NEVER BOTH AT THE SAME TIME. You should discover in which moment the ship can be destroyed, and in which moment the plane can be destroyed, use that moment to destroy them, and do not waste ammunition. (Screen 4). Remember the following instructions. A symbol at the top of the console of your Center of defense indicates that one of your enemies (the ship or the plane) is closer than 500 meters, so you should use your time to destroy it. Whenever you are not able to destroy your enemies it is better not to shoot them, so that you can save ammunition. Pay attention, because ship and planes approach at great speed. If do not have any doubts, press B to continue. Good luck!"

Instructions were followed with twelve A:R1-O1 and 12 B:R2-O2 trials, randomly intermixed. Each trial was divided in pre and stimulus periods. During the Pre period the ship and the plane were presented without the discriminative stimulus for 4 sec. Responding during this period was not reinforced. During the Stimulus period the plane and the ship were presented accompanied by the relevant discriminative stimuli, depending on the trial. The Stimulus period lasted 4 sec. Correct responses were reinforced under a variable interval schedule with a mean of 2.5 sec., and a range between 1 and 4 sec.

Extinction. This phase began immediately after the discriminative training phase ended, without any indication to participants that the phase had changed. During extinction, only one of the discriminative stimuli was presented (A for half of the participants and B for the other half). Extinction trials were identical to discriminative trials with the exception that responses were not reinforced. Twelve extinction trials were conducted. Every 4 trials the following message appeared on the screen:

"Remember. Whenever you cannot destroy any of your enemies, it is better not to shoot the weapons so that you do not unnecessarily lose ammunition. Press the B key to continue."

Test. One A:R1, and 1 B:R2 trials was presented in extinction. The order in which the stimuli were presented was counterbalanced between subjects.

Dependent variable and statistical analysis

Responses per minute in R1 and R2 were recorded throughout training, and evaluated by analysis of variance (ANOVA). The rejection criterion was set at $p< .05$.

Results and Discussion

The top panel of Figure 1 presents the mean response rate during Pre and Stimulus periods across the 12 trials of acquisition for the extinguished and non extinguished stimuli (Left), and the 12 trials of extinction for the extinguished stimulus (Right). Response rates increased across acquisition training regardless of the stimulus, while decreased during extinction training for the extinguished stimulus.

A 2 (Period, pre vs. stimulus) x 2 (Extinction) x 2 (Trial) ANOVA conducted with the acquisition data found a significant main effect of Period, $F(1,7)= 39.68$ (MSE= 33404.46) and Trial, $F(11,77)= 5.15$ (MSE= 1566.78). Most important, the Period by Trial interaction was also significant, $F(11,77)= 7.88$ (MSE= 809.72). No other effects or interactions were statistically significant, largest $F(11,77)= 1.56$ (MSE = 1609.52). Subsequent analyses conducted to explore the stimulus by trial interaction

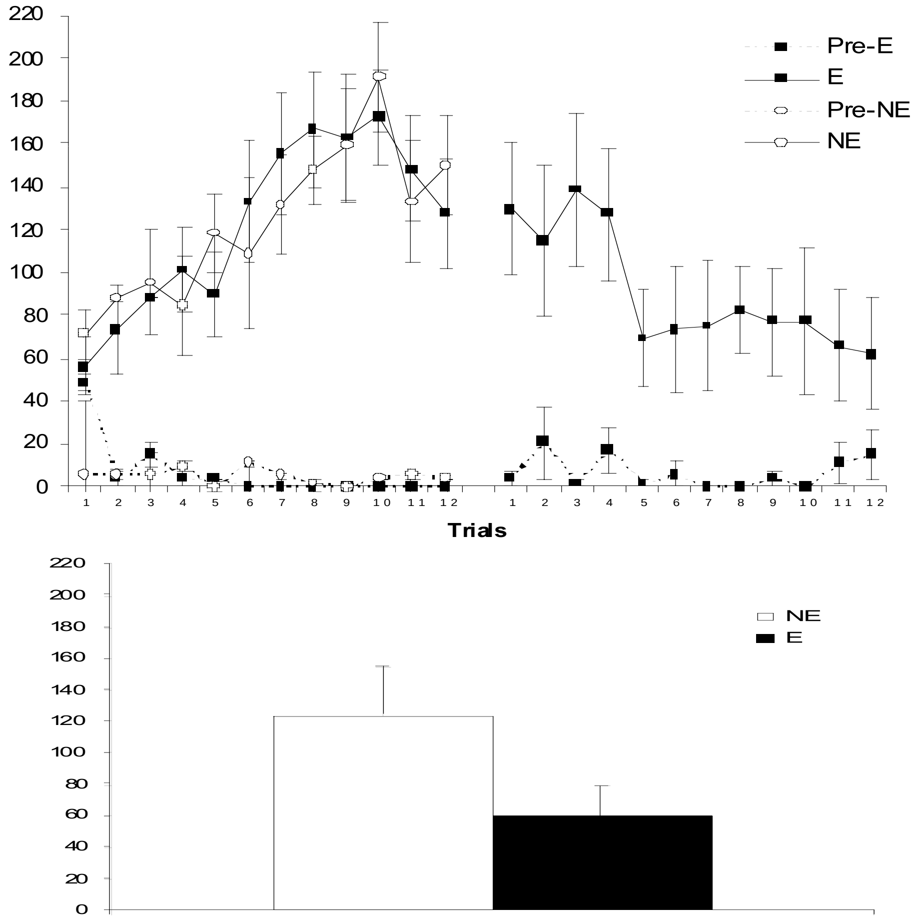

Figure 1. The top panel presents the mean response rate during the Pre and the Stimulus periods across the 12 trials of acquisition for the extinguished (E) and non extinguished (NE) stimuli (left) and the 12 trials of extinction of E (right). The bottom panel presents the mean response rated in the presence of NE and E during the final test of Experiment 1. Error bars denote standard errors of the mean.

found that the simple effect of Trial was significant during the Stimulus period, $F(11,77)= 7.40$ (MSE = 2877.03), but it was not significant during the Pre period, $F(11,77)= 1.80$ (MSE= 477.88). That is, discriminative training produced an increase in the response rate during the Stimulus period, while responding during the Pre period remained low.

A 2 (Period, pre vs. stimulus) x 12 (Trial) ANOVA conducted with the extinction data found significant main effects of Period, $F(1,7)= 12.97$ (MSE= 26252.51), and Trial, $F(11,77)= 2.34$ (MSE= 1546.34). The Period by Trial interaction was also significant, $F(11,77)= 2.49$ (MSE= 1226.01). Subsequent analysis conducted to explore the Period by Trial interaction found that the simple effect of trial was significant during the Stimulus period, $F(11,77)= 2.65$ (MSE= 2369.44), but it was not significant during the Pre period, $F(11,77)= 1.06$ (MSE= 402.91). Thus, the response rate during the stimulus decreased with the extinction treatment.

The bottom section of Figure 1 presents the mean response rate during the stimulus for the extinguished and non-extinguished stimuli during the test. Response rate during the extinguished stimulus was significantly lower than during the non-extinguished stimulus, $F(1,7)= 8.40$ (MSE= 2376.56). Responding during the Pre period was zero regardless of the stimulus.

To summarize, discriminative training led to an increase in the rate of responding during the stimulus while this rate decreased in the absence of the stimulus (Pre period). The rate of responding during the stimulus decreased during extinction, and this decrease was not generalized, or generalized little, to the response that was not extinguished. Thus, the procedure designed in Experiment 1 is adequate for the study of instrumental conditioning and extinction in human beings.

Experiment 2

The technique presented in Experiment 1 allows for detecting acquisition and extinction of instrumental learning in humans. The aim of Experiment 2 was to evaluate part of the contents of human instrumental learning by using the transfer technique (e.g., Colwill & Rescorla, 1988). Specifically, this experiment was conducted to assess whether an association between the discriminative stimulus and the outcome during instrumental acquisition forms. Additionally, the state of such association after extinction was also evaluated.

The design of the experiment is presented in Table 2. Two instrumental responses (R1 and R2) were trained with two different outcomes (O1 and O2). In a subsequent phase, two different responses (R3 and R4) were followed by the same outcomes, so that R1 and R3, and R2 and R4 shared the same outcomes. During discriminative training, R3 and R4 were reinforced only in the presence of discriminative stimuli (A and B). Once the discriminative training was finished, either R3 or R4 were extinguished in the presence of its respective discriminative stimulus. During the test, response to R1 and R2 was evaluated in the presence of the discriminative stimuli that were previously associated to R3 and R4. An S^D-O association should show as a greater responding on R1 in the presence of A, and R2 in the presence of B, the stimuli that were previously trained with the same outcomes. According to the results obtained in nonhuman animals,

Table 2. Design of Experiment 2.

Response training		Discrimination Training	Extinction	Test
R1-O1	R3-O1	A: R3-O1	A: R3- or B: R4-	A: R1 vs. A: R2
R2-O2	R4-O2	B: R4-O2		B: R1 vs. B: R2

Note. A, and B were a red rectangle and a blue oval. R1 and R2 were the orange and the green keys (I and M). R3 and R4 were the white and black keys (F and J). O1 and O2 were ship and plane destruction. Stimuli, responses, and outcomes were counterbalanced across participants. See text for details.

extinction should not affect transfer (e.g., Colwill y Rescorla, 1988; Rescorla, 1992).

Method

Participants and apparatus

Eight students participated in the experiment. Except were noted, participants and apparatus were identical to the ones used in Experiment 1.

I and M keys were covered with green and orange stickers, and were counterbalanced as R1 and R2. F and J keys covered with white and black stickers were counterbalanced as R3 and R4.

Procedure

Response training. After finishing R1 and R2 training, the following instructions appeared:

> "Your ammunition is gone and it is useless to destroy your enemies. We have prepared two new weapons (more powerful) that you can use by pressing the WHITE and BLACK keys. From now on you should use those keys (DO NOT USE THE ORANGE AND GREEN KEYS) to destroy ships and planes (press the B key to continue)".

R3 and R4 training was identical to the training of R1 and R2.

Discriminative training. Training in this phase was identical to that conducted in Experiment 1, except for being conducted with R3 and R4.

Extinction. Extinction was conducted with A:R3 for half of the participants and with B:R4 for the other half.

R1 and R2 retraining. The following message was presented at the end of extinction:

> "We are in trouble. Your weapons are failing again. During this period we have replenished your original weapons (the ORANGE and GREEN keys), so that from now on you should use them again to efficiently destroy the ships and the planes.

(Press B to continue)".

Three trials with R1 and 3 trials with R2 were randomly intermixed. Training was otherwise identical to the initial response training.

Transfer test. The test was identical to the one conducted in Experiment 1. A, and B were presented while participants were responding on R1 and R2.

Results and Discussion

Acquisition and extinction proceeded uneventfully. The top panel of Figure 2 presents the response rate during the Pre and Stimulus periods across the 12 trials of discriminative training for the extinguished and non-extinguished stimuli (Left), and across the 12 trials of extinction for the extinguished stimulus (Right). Response rate during the Stimulus period increased across the acquisition trials, while it decreased during extinction for the extinguished stimulus. Response rate during the Pre period remained low.

A 2 (Period, pre vs. stimulus) x 2 (Extinction) x 2 (Trial) ANOVA conducted with the acquisition data found significant main effects of Period, $F(1,7)= 33.67$ (MSE= 14729.46) and Trial, $F(11,77)= 2.66$ (MSE= 716.31). Most important, the Period by Trial interaction was also significant, $F(11,77)= 4.14$ (MSE= 457.57). No other effects or interactions were statistically significant, largest $F(1,7)= 2.30$ (MSE= 122.88). Subsequent analysis conducted to explore the Stimulus by Trial interaction found that the simple effect of Trial was not significant during the Pre period, $F< 1$, but it was significant during the Stimulus, $F(11,77)= 3.72$ (MSE= 1283.60). Replicating the results obtained in Experiment 1, discriminative training produced an increase in the response rate during the Stimulus.

A 2 (Period, pre vs. stimulus) x 12 (Trial) ANOVA conducted with the extinction data found a significant main effect of Stimulus, $F(1,7)= 13.64$ (MSE= 16780.58). The main effect of Trial and the Stimulus by Trial interaction were not significant, largest $F(11,77)= 1.60$ (MSE= 500.59). However, planned comparisons found that the simple effect of Trial was significant during the Stimulus, $F(11,77)= 1.97$ (MSE = 902.56), but it was not significant during the Pre, $F< 1$. As in Experiment 1, extinction was shown as a decrease in response rate in the presence of the extinguished stimulus.

The most interesting results of this experiment are shown in the bottom section of Figure 2. The left side of this figure shows the mean response rates in the presence of the discriminative stimuli on the response with which it was trained, and the other response that shared the same (Same) or different (Diff) outcome. The right side shows the same arrangement when the S^D-Outcome had been extinguished. The figure shows that the discriminative stimulus transferred control (response rate higher in Same than in Diff) for the non extinguished stimulus. This effect of transfer was much less evident for the S^D that underwent extinction. A 2 (Extinction) x 2 (Transfer) ANOVA found a significant main effect of Transfer, $F(1,7)= 9.09$ (MSE= 1237.50), but no main effect of extinction, $F(1,7)= 2.61$ (MSE= 269.20). Interestingly, there was a significant Extinction by Transfer interaction, $F(1,7)= 5.86$ (MSE= 1173.21). Subsequent analysis to explore

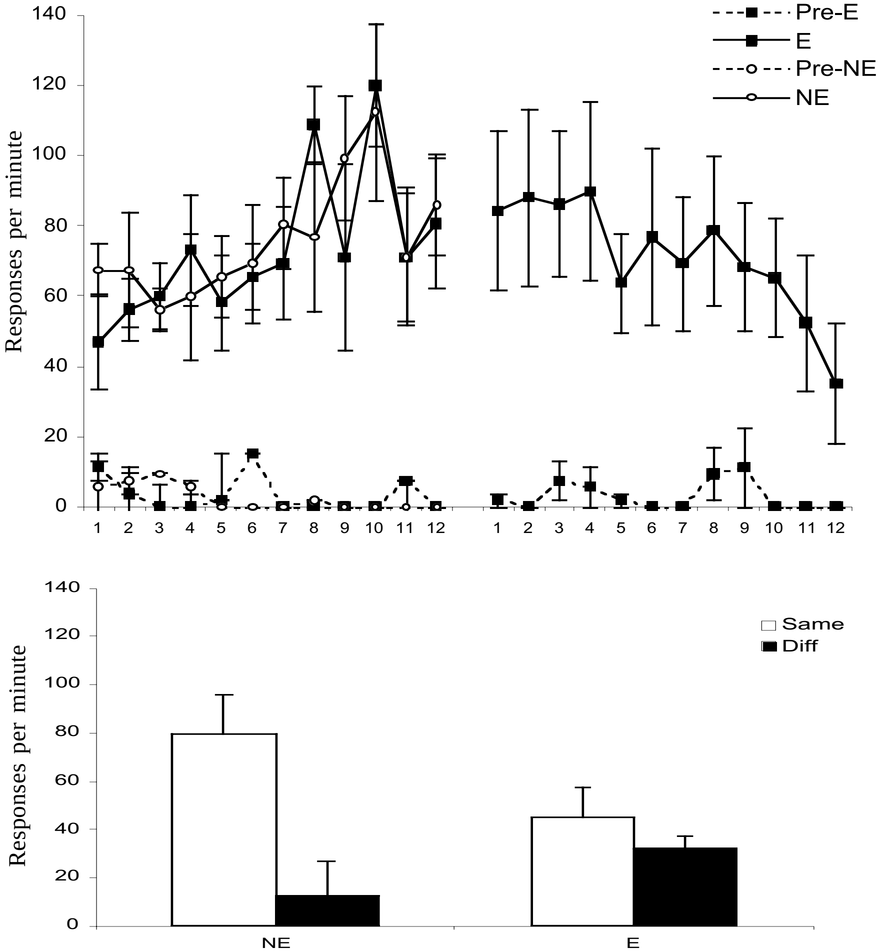

Figure 2. The top panel presents the mean response rate during the Pre and the Stimulus periods across the 12 trials of acquisition for the extinguished (E) and non extinguished (NE) stimuli (left) and the 12 trials of extinction of E (right). The bottom panel presents the mean response rate in the presence of the SD on the test. Open bars show responding on the response paired with the same outcome signaled by the SD. Solid bars show responding on the alternative not signaled by the SD. Left and right panels show the effects of extinction of the SD. Error bars denote standard errors of the mean

the Extinction by Transfer interaction found that the simple effect of Transfer was significant with the non extinguished stimulus, $F(1,7)= 26.35$ (MSE= 546.43), but it was not significant in the extinguished stimulus, $F< 1$. Thus, extinction eliminated the transfer effect.

Pre-stimulus response rates averaged 20.15. A 2 (Extinction) x 2 (Transfer) ANOVA found no significant main effects or interaction between factors, $F(1,7)= 1.2$ (MSE= 143.64).

To summarize, the transfer effect observed in the non-extinguished stimulus demonstrates the role of S^D-O association in human instrumental conditioning. Contrary to what has been found in nonhuman animals (e.g., Colwill & Rescorla, 1988; Rescorla, 1992), extinction eliminated the transfer effect, suggesting that extinction deteriorates the relationship between the discriminative stimulus and the outcome in human instrumental conditioning.

General Discussion

The main goals of this experimental series were to assess whether an S^D-Outcome relationship could be established within human instrumental conditioning, and whether this relationship was affected by extinction. Experiment 1 found that response-outcome pairings in the presence of a discriminative stimulus led to an increase in response rate in the presence of the stimulus while responding in the absence of the stimulus remained low. Omission of the outcome led to the extinction of the response in the presence of the stimulus. This extinction did not generalize to a non-extinguished response. Experiment 2 replicated these basic results. Additionally, Experiment 2 found evidence of the formation of an S^D-O association in instrumental learning that was eliminated by extinction.

Acquisition, extinction and the evidence of the establishment of a S^D-O association in human instrumental learning extend the results found in nonhuman animals (e.g., Colwill, 1994; Colwill y Rescorla, 1986, 1988; Rescorla, 1992). Additionally, the results of Experiment 2 complement the analysis of the contents of human instrumental learning begun by Vega *et al.* (2004) who found evidence of the formation of an R-O association in human instrumental learning. Experiment 2 of the present work suggests that an S^D-O association is part of what humans learn in instrumental conditioning. Additional research should be conducted to evaluate the contribution of S^D-R and S^D(R-O) associations to human instrumental performance, associations that have been shown to contribute to nonhuman instrumental behavior (e.g., Colwill, 1994).

The most interesting though unexpected result of Experiment 2 was the finding that extinction annulated the transfer effect. According to these results, extinction in human instrumental learning leads to the elimination of the S^D-O association, a result that is in disagreement with what has been repeatedly found in nonhuman animals (e.g., Colwill y Rescorla, 1988; Rescorla, 1992). Extinction in nonhuman animals does not seem to affect transfer, suggesting that the S^D-O association remains active after extinction. This kind of result together with those that argue against formation of R-NoO associations during extinction (Rescorla, 1993b) led some researchers to suggest that extinction in nonhuman animals may imply the learning of an inhibitory association between the stimulus and the response the subject emits during extinction (Rescorla, 1993a). Along the same line of reasoning, the results of Experiment 2 suggest that human instrumental extinction may eliminate the association between the discriminative stimulus and the outcome. The difference between the results found in this experiment and those found with non human animals prompts the idea that, contrary to what it has been found in non human animals, extinction of instrumental conditioning in humans may also lead to the elimination of the R-O association established during acquisition (Vega *et al.*, 2004).

Caution in accepting this interpretation is in order. The tasks used in most human learning experiments, including the ones reported here, lack of biological relevance for participants, unlike the ones usually employed in nonhuman animal experiments. The use of biologically relevant stimuli has shown to be a factor in producing differences between nonhuman and human animals with respect to backward blocking, a phenomenon that was originally thought to be found exclusively in human animals (see Denniston, Miller, & Matute, 1996; Miller & Matute, 1996a). Thus, there are grounds in the literature to suggest that the difference between the results found here and the results reported in the nonhuman animal literature might be due to the difference in the motivational value of the stimuli used as reinforcers.

The explanation given by Rescorla (2001) about the lack of effects of extinction upon transfer might give us a hint as to why these differences might appear, based on the differential salience of biologically relevant and irrelevant stimuli. The effects of extinction seem to be response specific, suggesting that extinction in animal standard conditioning might result in an inhibitory association between the stimuli and the response that the animal performs during extinction (e.g., Colwill, 1991; Rescorla, 1997). Rescorla (1991) suggests that frustration elicited by removal or reward during extinction might be conditioned to the particular responses that are evoked when it occurs, explaining the high degree of response specificity observed in his experiments. Note that this account is based on the emotional effects of removal of an expected reward, something that we can assume to be correlated with the importance of the outcome. In the absence of biologically relevant outcomes, the emotional result of removing the outcome during extinction might be assumed to be negligible, and that might diminish response specificity during extinction learning. That could be a factor explaining the difference between the results reported in this paper, and the ones reported in the nonhuman animal literature. These are only speculations at this point, and additional research will be needed to decide whether these differences are prompted by differences in the tasks, or in the processing of the information between nonhuman and human animals.

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