The state of transfer of stimulus control after extinction in human instrumental conditioning: A key factor in therapy strategies based in nonhuman animal research

Abstract

Previous research has shown that instrumental training can encourage the formation of binary associations between the representations of the elements present at the time of learning, that is, between the discriminative stimulus and the instrumental response (the S–R association), between the stimulus and outcome (the S–O association), and between the response and outcome (the R–O association). Studies with rats have used transfer procedures to explore the effects of discriminative extinction (i.e., extinction that is carried out in the presence of the discriminative stimuli) on these three binary associations. Thus, a reduction in the response rate of the extinguished response (R) can be detected in situations involving a different discriminative stimulus that was associated with the same outcome, and to unextinguished responses controlled by the discriminative stimulus (S) and associated with the outcome (O). These transfer effects suggest that R-O and S-O associations remain active after extinction in non-human animals. We carried out an experiment to explore these post-extinction transfer effects in humans using a within-subject design. Contrary to non-human reports, the S-O association was affected by discriminative extinction, suggesting differences in the associative structure of instrumental conditioning in human and nonhuman animals that should be considered by those therapeutic strategies based in nonhuman animal research aimed to reduce unhealthy instrumental behaviors in human beings.

Keywords**:** Human instrumental conditioning; Extinction; Contents of learning; Transfer test.

Short Public Significance Statement

Animal research has shown that when a response stops being followed by an outcome (i.e., when it is extinguished) the underlying associations that maintained that response remain active. The experiment presented here reveals that extinction of human voluntary responding may be an exception to this general rule, a result that is quite relevant from a clinical point of view, as most psychological treatments involve some form of extinction.

Many unhealthy behaviors in humans are based in learned behaviors such as smoking, excesive drinking or excesive eating (Harrington, 2008; Houben & Jansen, 2011; Schroeder, 2007). Associative theories explain this learned behaviour as the result of associations established among the elements that represent the learning situation. A precise characterization of the effects of experience on these associations is at the base for developing a number of effective clinical interventions aimed at controlling pathological responses. Along these lines, instrumental conditioning arises as the learning process that allows studying how those behaviors are influenced by their consequences (e.g., Dickinson & Balleine, 1993).

Extinction is one of the most reliable and quick procedures to reduce learned behaviors, and as such, it is at the base of different cognitive-behavioral therapies that aimed for a change in the behavior of the individual (e.g., Craske et al., 2008; Jansen, Schyns, Bongers, & van den Akker, 2016; Laborda, McConnell, & Miller, 2011; Laborda, Polack, Miguez, & Miller, 2014). Many of those strategies are based in studies with nonhuman animals (e.g., Conklin & Tiffany, 2002; Wathen & Podlesnik, 2018). As one of the key issues within clinical psychology is reducing or even eliminating maladaptive behaviors, the study of the contents and mechanism of instrumental extinction has drawn an important deal of attention, both, from the experimental and translational approaches. Thus, a good knowledge about instrumental extinction is expected to allow for developing more successful therapeutic strategies (e.g., Bouton, Winterbauer, & Todd, 2012).

However, it is not unusual that clinical procedures based on translational research fail to produce the desired effect, either because the maladaptive behavior is not fully eliminated, or because there is a relapse of the extinguished behavior (e.g., Dunsmoor, Niv, Daw, & Phelps, 2015; Podlesnik, Kelley, Jimenez-Gomez, & Bouton, 2017). Although the sources that explain therapy failures may be many and complex, some of the limitations on the use of nonhuman animals-based therapy procedures could be related to differential processing mechanisms in human and nonhuman animals regarding how extinction affects associative structures in different species. This concern is at the base of the experiment presented here.

Associative structure in instrumental learning

Any instrumental learning situation involves three main elements: the instrumental response (R), the reinforcer or outcome that follows the instrumental response (O), and the environmental stimuli or context (S) present at the time of learning. Therefore, three binary and one hierarchical associations may be established among these three elements: R-O, S-O, S-R, and S(R-O) (e.g., Gámez & Rosas, 2007; Hall, 2002).

The study of the associative structure of instrumental learning in nonhuman animals has often used different transfer procedures (e.g., Colwill, 1994; Colwill & Rescorla, 1988, 1990). For instance, Colwill and Rescorla (1988) used the following transfer procedure to evaluate the S-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, in the absence of discriminative stimuli. Finally, animals were tested in extinction in the presence of the two discriminative stimuli with the two responses that were trained in the absence of them. Each discriminative stimulus specifically facilitated the response with which it shared the outcome. Using an analogous procedure, Gamez & Rosas (2007, Experiment 1) reported similar results in human instrumental conditioning. Gamez and Rosas (2007, Experiments 2 and 3) also found evidence indicating that instrumental training established an S-R and a R-O association linking the instrumental response with both its outcome and the discriminative stimulus (see Colwill, 1994 for similar results). The combination of the results summarized here suggests that the associative structure established during instrumental discrimination training in rats and humans may be alike.

Rescorla (1993a) also used a transfer procedure to explore the effects of instrumental extinction on the associative structure in rats. Results showed that extinction does not seem to eliminate S-O and R-O associations, suggesting that extinction mainly affects the S-R association. In Experiment 1, he trained rats to perform four instrumental responses to get two different outcomes in the presence of different discriminative stimuli. In the first stage of the experiment, performing R1 and R2 were followed by O1 or O2 in the presence of discriminative stimuli S1 and S2 (S1:R1-O1; S2:R2-O2). In the second stage, two different responses (R3 and R4) were trained with the same reinforcers (O1 and O2) in the presence of discriminative stimuli S3 and S4 (S3:R3-O1; S4:R4-O2). During the extinction phase, R1 was no longer reinforced in the presence of S1 (S1:R1-). Thus, the combination S1:R1-O1 was extinguished, while the rest of combinations were not. Finally, two transfer tests were conducted with the goal of exploring the state of each association after extinction. The first transfer test was conducted to evaluate the state of the R-O association, while the second transfer test was conducted to evaluate the state of the S-O association. During the R-O test rats could perform R1 and R2 in the presence of S3 or S4. Regardless of whether the response was extinguished or not, rats responded more in the response option that had been followed by the same outcome that the present discriminative stimulus. During the S-O test, rats could perform R3 and R4 in the presence of S1 or S2. Animals preferentially chose the response option that had been followed by the same outcome that followed the discriminative stimulus, regardless of whether this stimulus had been extinguished or not. Neither extinction of the instrumental response (R1) nor extinction of the discriminative stimulus (S1) prevented transfer, suggesting that extinction did not affect R-O and S-O associations established during instrumental training.

Studies about the associative structure of human instrumental extinction are scarce and their results do not seem to be aligned with what it has been found in rats. Gamez and Rosas (2005) found that selective transfer dissapeared after discriminative instrumental extinction (S:R1-), suggesting that extinction breaks the S-O association in humans. Hogarth et al. (2014) replicated the attenuation of transfer by discriminative extinction, whilst a Pavlovian extinction (S-) led the transfer effect intact.

To our knowledge, no study with human partricipants has explored whether transfer of stimulus control disappears when the instrumental response is extinguished in the absence of discriminative stimuli, that is, whether R-O association is affected by extinction or not. Note that any behavioural theraphy based on extinction will have a limited effectiveness if, as reported in rats, this association remains active after the intervention (e.g., pathological associations may be shown with the same or with a different behavior from the extinctinguished one when the discriminative stimuli are different to those present when extinction took place).

The main goal of the present experiment is to assess the state of the R-O association after extinction by testing the extinguished instrumental response in the presence of a different discriminative stimulus. Additionally, and given the discrepancies between species and its potential relevance for some therapeutic interventions, we will also assess the state of the S-O association after extinction in order to test further if extinction affects the S-O association in human beings (Gamez & Rosas, 2005; Hogarth et al., 2014).

The experiment was conducted in four phases: Acquisition, Extinction, R-O Test, and S-O Test (see Table 1). Acquisition was structured in two stages. In the first stage, each participant received 24 S1:R1-O1 and 24 S2:R2-O2 trials. The second stage consisted on 24 S3:R3-O1 and 24 S4:R4-O2. In both stages trials were presented randomly intermixed. Once the discriminative training was finished, thirty extinction trials with the S1:R1- combination were presented in order to extinguish R1 in the presence of its discriminative stimulus. Finally, R-O and S-O tests were presented to assess both associations (test order was counterbalanced across participants).

INSERT TABLE 1 ABOUT HERE

In R-O Test, participants received one trial in extinction with S3 and another one with S4. Available responses were those used along the first phase of acquisition (S3: R1/R2, and S4: R1/R2). Participants were expected to perform on a higher extent the response that shares the outcome with the discriminative stimulus presented (i.e., S3: R1>R2 and S4:R2>R1) by means of the R-O association. However, if extinction affects the R-O association, no differences between R1 and R2 are expected when S3 or S4 are presented. Thus, if as reported with rats, extinction of R1 does not affect R1-O1 association, participants should perform R1 on a higher extent than R2 when S3 is presented (as S3 signals the availability of O1).

In S-O Test, participants received one trial in extinction with S1 (previously extinguished) and another one with S2. Available responses were those used along the second phase of acquisition (S1: R3/R4 and S2: R3/R4). As in R-O test, participants were expected to perform on a higher extent the response that share the outcome with the discriminative stimulus presented (S1: R3>R4 and S2:R4>R3). If extinction affected the S-O association, no differences between R3 and R4 when S1 is presented were expected.

Method

Participants

Thirty-two undergraduate students at the University of Jaén participated in this experiment in exchange for course credit (28 women, 4 men; M_{age} = 21.34 years, age range 18–26 years). None of them had previous experience with the task. All participants gave informed consent in advance, and were informed about their right to withdraw from the procedure at any time. Procedures were aproved by the local ethical committee.

Apparatus and stimuli

Participants were trained individually in six adjacent isolated cubicles. Each cubicle had a PC on which the task was presented. The procedure was implemented using SuperLab Pro (Cedrus Corporation) software. Participants played a computer game in which they were required to defend Andalusia from air and land attacks.The main screen presented a black view simulating participant's control panel (see details on Figure 1). On top of the screen there were four rectangles that could be coloured in red, navy blue, light blue, and grey (colours were counterbalanced as discriminative stimuli S1, S2, S3, and S4).The two attackers, a plane and a tank, were presented on a natural landscape: a Cabo de Gata beach (Almería, Spain). The plane was presented in the sky, at the top right area of the screen, while the tank was presented on the beach, at the bottom left area of the screen. Both attackers could appear in one of two different positions within their respective areas on the screen, giving the impression of movement.

INSERT FIGURE 1 ABOUT HERE

Instrumental responses were all clicking on one of four keys in the computer screen labelled as 1, 2, 3, or 4. The keys were placed at the bottom area of the bunker view. Responses were made available in pairs, that is, participants may respond choosing between R1 and R2, or between R3 and R4, but they were never required to choose among the four possibilities.

Destruction of the tank and the plane were counterbalanced as Outcome 1 (O1) and Outcome 2 (O2) across participants.

Procedure

The instructions and all necessary information were presented in Spanish on the computer screen. Participants interacted with the computer using the mouse (left button). Instructions were presented in five screens using a black Times New Roman font against a light yellow background to emulate the appearance of an old document. To advance the instruction screens participants had to click on a button labelled "next" placed on the right bottom of the screen. Each participant was initially asked to read the following instructions:

[Screen 1] "Andalusia is being attacked by land and air. You are placed in the only bunker able to face up the attackers. The monitor presents the bunker's viewer. You have to defend us from the enemies that you will see from there. [Screen 2] Your technology and weapons are older than theirs, so you will need to shoot several times to destroy them. To shoot, click with the left button of the mouse on keys 1 and 2 (or 3 and 4, depending on the counterbalancing). One of these two keys fires anti-aircraft missiles and the other one anti-tank torpedoes. [Screen 3] Your weapons range is 500 metres. If your enemies are farther, you will not be able to reach them. However, a coloured rectangle will appear on the top of your screen to indicate that one of your enemies (either the tank or the plane) is less than 500 metres away from you, so that it can be destroyed. Use the opportunity to destroy it, making the most of your ammunition. [Screen 4] The battle begins! Remember that you can destroy only one attacker at any given time, so you will have to discover which one is currently within the shooting range. Remember not to waste the ammunition on the attackers that are beyond the shooting range. Call the experimenter if you have any doubts. Otherwise, click with the mouse to begin. GOOD LUCK!".

The first stage of adquisition phase ended with the following instructions: "Your ammunition is deteriorated, and it is not useful to destroy your enemies anymore. We have provided you with two new weapons that can be used by clicking with the mouse on keys 3 and 4 (or 1 and 2, depending on the counterbalance). Once again, you have to discover when you will be able destroy the tanks, and when the planes. The battle continues!". The second stage of acquisition 2 started after these instructions and once completed, the next instructions were presented: "Your weapons are failing again! Try using the initial armament, that is, keys 1 and 2 (or 3 and 4, depending on the counterbalance). Pay attention to the symbols appearing on the screen to identify which enemy can be destroyed". After thirty extinction trials R-O and S-O test were presented counterbalanced.

Each trial was divided in Pre and Stimulus period. During the Pre-period, the tank and the plane were presented without the discriminative stimulus for 4 seconds, and responding was not reinforced (see left panel of Figure 2). During the Stimulus period, the tank and the plane were presented accompanied by the relevant discriminative stimuli, depending on the trial (see central panel of Figure 2). During acquisition, correct responses were reinforced by making the enemies to blow up (see right panel of Figure 2). We used a VI2 reinforcement schedule in which the availability of reinforcers oscillated randomly between 1 and 3 seconds. Once the reinforcer was available, the trial continued until the participant gave the correct response.

INSERT FIGURE 2 ABOUT HERE

Participants were forced to choose the correct response to end the trial. Extinction and acquisition trials were identical except that responses were never reinforced. At testing, none of the responses was reinforced and the duration of the stimulus period was 4 s. Each test contained only 1 trial to limit learning effects associated with this phase as much as possible.

Dependent variable and statistical analysis

Total mouse clicks on each key during Pre and Stimulus periods were recorded and transformed to responses per minute. Responding was evaluated by repeated measures analysis of variance. The rejection criterion was set at $p < .05$, and effect sizes were reported using generalized eta-squared (η_{ges}^2). Error bars depicted in the figures denote within-subject standard errors following Cousineau-Morey corrections (O'Brien & Cousineau, 2014).

Results

Acquisition. On the last trial of acquisition, mean response rate in the reinforced response alternative (and the standard error of the mean) were 0, 1.87 (±1.87), 1.87 (±1.30) and 0 during the Pre period and 50.62 (±3.85), 56.25 (±5.34), 59.06 (±5.42) and 59.53 (±5.19) during the Stimulus period for stimuli S1, S2, S3 and S4, respectively. Response rates in the unreinforced response alternative were 1.87 (±1.87), 0, 0 and 0, during the Pre period, and 7.03 (±2.51), 14.53 (±7.63), 4.68 (±2.64), and 2.81 (±1.95) during the Stimulus period, for stimuli S1, S2, S3 and S4 respectively. Therefore, at the end of acquisition, responding seems to be higher during the Stimulus period than during the Pre period, regardless of whether the response was reinforced or not. Statistical analysis confirmed these impressions (see details in Appendix A). Note that participants are required to save their ammunition in a situation in which they are also instructed about the limited range of their weapons (they could only reach enemies when S is presented). These instructions, together with the explicit requirement of saving the ammunition, make the effect previously reported congruent with the cover story: to optimize performance participants responded on a higher rate when they can reach enemies, that is, on Stimulus-period. Thus, participants differentially chose the alternative that was followed by reinforcement in the presence of the stimulus, but not in its absence.

Extinction. To test the effect of the extinction treatment, we can compare performance at the end of the acquisition training with performance at the end of the extinction training. On the last trial of acquisition (24), mean rate of responding when the to-be-extinguished stimulus (S1) was absent (Pre-period) was 0, whereas mean rate of responding when this stimulus was present (Stimulus-period) was 52.03 (±3.81). However, on the last trial of extinction (30) these rates were 0.47 (±2.65) and 14.06 (±3.36), respectively. That is, response rate at the end of extinction seems to be lower than response rate at the end of acquisition only when the stimulus was present

(Stimulus period). These impressions were statistically confirmed (see detailed analysis on Appendix A).

R-O Test. Figure 3 depicts the mean rate of responses per minute on R-O Test when S3 and S4 were present (Stimulus-period) and absent (Pre-period). Separate rates for the extinguished and non-extinguished responses (R1 and R2, respectively) are presented for stimulus-period. As expected, and independently of extinction, participants performed those responses previously paired with the same outcome (Same) on a higher rate than the alternative ones (Different).That is, transfer seems to remain unaffected by extinction when the response that has been previously extinguished is tested. A 2 (Period, Pre vs. Stimulus) x 2 (Stimuli, S3 vs. S4) x 2 (Response, Same vs. Different) x 2 (Test order, R-O followed by S-O vs. S-O followed by R-O) ANOVA found significant main effects of Period, F (1, 30) = 39.53, p <.001, η_{ges}^2 = .11, and Response, F (1, 30) = 18.63, p <.001, η_{ges}^2 = .03. Moreover, only Period x Response interaction was significant, F (1, 30) = 18.75, p <.001, η_{ges}^2 = .03. No other effects or interactions were significant, largest F (1, 30) = 3.19, p = .084. Detailed analysis carried out to explore Period x Response interaction, showed a significant simple effect of Response only in the Stimulus-period, F (1, 31) = 19.92, p <.001, η_{ges}^2 = .16, that is, Same response was performed on a higher rate than Different response only when the stimulus was present, showing a transfer effect regardless of extinction.

INSERT FIGURE 3 ABOUT HERE

S-O Test. Figure 4 shows mean responding rate per minute when S1 and S2 were present (Stimulus-period) and absent (Pre-period). Rates for R3 and R4 when the extinguished and non-extinguished stimuli were presented (S1 and S2 respectively) are depicted for Stimulus period. When the stimulus presented has not undergone extinction (S2), there is a clear difference between performing the response that shared an outcome with S2 (Same) and the response that did not share outcome with S2 (Different). However, when the stimulus presented is the one previously extinguished (S1) differences between responses rates on same and different conditions are attenuated. Statistical analysis confirmed these impressions. A 2 (Period, Pre vs. Stimulus) x 2 (Stimuli, S1 vs. S2) x 2 (Response, Same vs. Different) x 2 (Test order, R-O followed by S-O vs. S-O followed by R-O) ANOVA found significant main effects of Period, F (1, 30) = 59.84, p <.001, $\eta_{ges}^2 = .18$, and Response, F (1, 30) = 10.19, p =.003, $\eta_{ges}^2 = .03$. Period x Response, F (1, 30) = 11.99, p =.002, $\eta_{ges}^2 = .03$, Stimuli x Response, F (1, 30) = 30.27, p <.001, $\eta_{ges}^2 = .04$, and Period x Stimuli x Response, F (1, 30) = 23.41, p <.001, $\eta_{ges}^2 = .05$, interactions turned out to be significant as well. Detailed analyses of the Period x Stimuli x Response interaction showed no effect of Response on Pre-Period, nor on S1 neither on S2 stimuli, *F<1* (note that S is not presented along this period, and that non-extinguished stimulus refers to the one that will be presented on that trial during the Stimulus period). Stimuli x Response interaction was significant on the Stimulus period, F (1, 31) = 27.82, p <.001, $\eta_{ges}^2 = .47$. Follow-up comparisons to explore this interaction found that the simple effect of Response was significant only for S2, F (1, 31) = 28.66, p <.001, $\eta_{ges}^2 = .28$, suggesting that extinction breaks the S-O association.

INSERT FIGURE 4 ABOUT HERE

Discussion

The main goal of this experiment was to assess how an extinction treatment may affect the S-O and R-O associations established within human instrumental training. R-O Test found that transfer remained apparently unaffected by the extinction of the instrumental response, suggesting that extinction did not break the R-O association.

Given that no effects involving extinction were found, independence between extinction and R-O association can be assumed (see Rescorla, 1993a, 1993b, for a similar result in rats).

S-O Test found that the transfer effect disappeared after extinction, suggesting that extinction attenuates the strength of the S-O association. This result replicates the one previously reported in human beings (Gámez and Rosas, 2005; Hogarth et al., 2014), but it seems to contradict the results reported in nonhuman animal research (e.g., Rescorla, 1992, 1993a). Rescorla (1993a) pointed out that extinction makes the stimulus to lose its excitatory instrumental properties but that it does not affect its ability to transfer control to other responses trained with the same outcome. In other words, instrumental extinction in rats seems to establish inhibitory associations between the stimulus and the extinguished response, leaving the associations between the stimulus and the outcome intact. Alternatively, results reported here suggest that instrumental extinction in humans may lead to the formation of both, S-NoR and S-NoO inhibitory associations.

The unique value of the present experiment is to show that the R-O association is not affected by extinction in the same situation in which extinction did have a weakening effect on the S-O association. Finding the same results within the same within-subject design, and with the test order counterbalanced allows to conclude that the extinction procedure used in this experiment differentially affected participants' associative structure. In other words, the same extinction procedure differentially affected S-O and R-O associations.

Moreover, the results reported in this experiment show that, even when a response dissappears when is no longer followed by the outcome with which it has been trained, the association between the response and the outcome is not fully eliminated, explaining why relapse of the instrumental response often appears after using therapies based in extinction of the instrumental response (e.g., Laborda et al., 2011; Podlesnik et al., 2017). Results from studies conducted with nonhuman animals suggest that the same would be true for the responses that are associated with the stimulus. In other words, animal studies suggest that instrumental extinction will not eliminate the possibility of maladaptive instrumental responses to be elicited by a different stimulus (e.g., Rescorla, 1993a). However, this does not seem to be true in humans as shown here and in other reports from the literature (Gámez and Rosas, 2005; Hogarth et al., 2014). Taken both results together it seems reasonable to suggest that psychological procedures focused in the extinction of the eliciting stimulus might be more useful to mitigate or eliminate maladaptive behaviours than psychological treatments focused in extinguishing the maladaptive behaviour itself.

At any rate, it should be noted that even though the procedure used in this experiment used a design akin to the one used by Rescorla (1993a), practical and ethical restrictions make impossible to completely parallel non-human procedures in a human learning paradigm. Thus, a main difference is that animal procedures typically involve biologically relevant settings achieved, for example, by food deprivation. These procedures impose ethical limitations that force us to to achieve the increased motivational value through a different strategy. We need participants to be motivated enough to perform as if the stimuli were biologically relevant, and to face the experimental setting with a clear goal. This is why we explicitly instructed participants about the sensors, the range of weapons or ammunition limitations among other the requirements to ensure motivation while reducing individual interpretations that may interfere with the actual requirements of the task (see a similar approach in Arcediano, Ortega & Matute, 1996; Nelson & San Juan, 2006). Additionally, we decided to use a procedure that has been shown to parallel animal instrumental learning phenomena in human participants (Gámez & Rosas, 2005; 2007; Gámez, León, & Rosas, 2017). However, it is unlikely that a human child playing a simple game and a hungry rat searching for food reach the same level of involvement. Thus, the question is whether procedural, rather than interspecies, differences between our study and that of Rescorla (1993a) may explain our results. Although we cannot completely rule out procedural differences as a source for the differences found in our experiment, it is important to note that there is additional evidence supporting our conclusions that has been collected by using a different procedure (see Hogarth et al., 2014). Nevertheless, procedural discrepancies between human and non-human subjects is a topic that has raised, and still raises, a great amount of interest for learning and comparative research (e.g. Miller & Matute, 1996; Alcalá, González, Aristizabal, Callejas-Aguilera & Rosas, 2018; Mitchell, De Houwer & Lovibond, 2009), and that remains an open debate deserving further research.

Finally, one potential limitation of our study in terms of external validity is related to the unequal sex ratio. Our sample is composed by a majority of women and a very reduced number of men. In this situation we cannot explore the potential contribution of sex to the effects reported here. Nevertheless, previous studies did not consider sex as a relevant factor for studying the associative structure of instrumental conditioning (e.g., Gámez & Rosas, 2005, 2007), and these learning processes are usually assumed to be general and present in all individuals.

Thus, future research should evaluate whether the results obtained in our experiment could be replicated in animals by using non-biologically relevant stimuli (e.g., using sensory preconditioning or second order conditioning) or whether they can be modulated by the use of biologically relevant stimuli in humans.

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Link to data in OSF: https://osf.io/pbuxj/

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Table 1

Design of the Experiment

Acquisition		**Extinction**	**R-O Test**	**S-O Test**
Stage 1	Stage 2			
24 S1: R1-O1, 24 S2: R2-O2	24 S3: R3-O1, 24 S4: R4-O2	30 S1: R1-	1 S3: R1- vs. R2- 1 S4: R1- vs. R2-	1 S1: R3- vs. R4- 1 S2: R3- vs. R4-

Note. Discriminative stimuli S1, S2, S3, and S4: red, navy blue, blue light, and grey, counterbalanced. R1, R2, R3, and R4: clicking on numbered keys to destroy the plane or the tank. O1 and O2: plane or tank destruction, counterbalanced. -: no outcome. Tests order was counterbalanced.

Figure 1. Screenshot of participants' control panel.

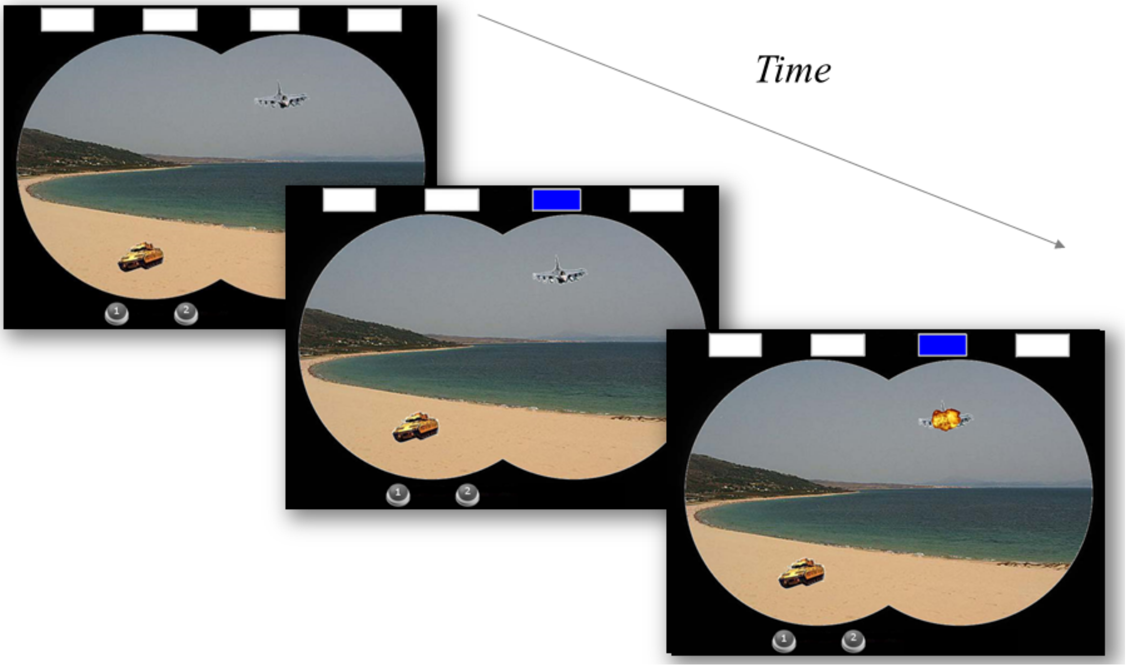

Figure 2. Trial structure on acquisition phase. From left to right: Pre period with R1 and R2 available, Stimulus period with discriminative stimulus (blue sensor is on), and Stimulus period with reinforcer (plane exploding).

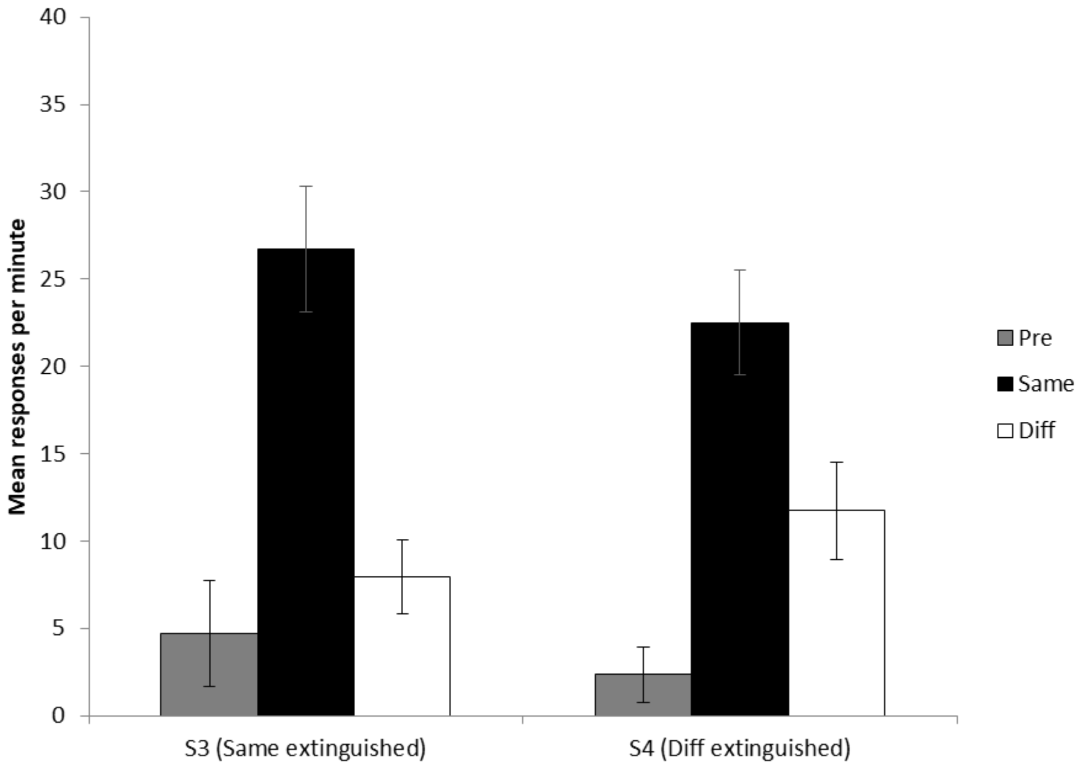

Figure 3. Mean response rate per minute in the absence (Pre) and in the presence of discriminative stimuli S3 and S4 during R-O Test. Rates for the extinguished (R1) and non-extinguished (R2) responses are presented when stimuli were present. Same refers to the response that shares the outcome with the discriminative stimulus presented on test (R1 when S3 is presented and R2 when S4 is presented). Diff refers to the alternative response (R2 when S3 is presented and R1 when S4 is presented). Error bars represent within-subject standard errors following Cousineau-Morey corrections.

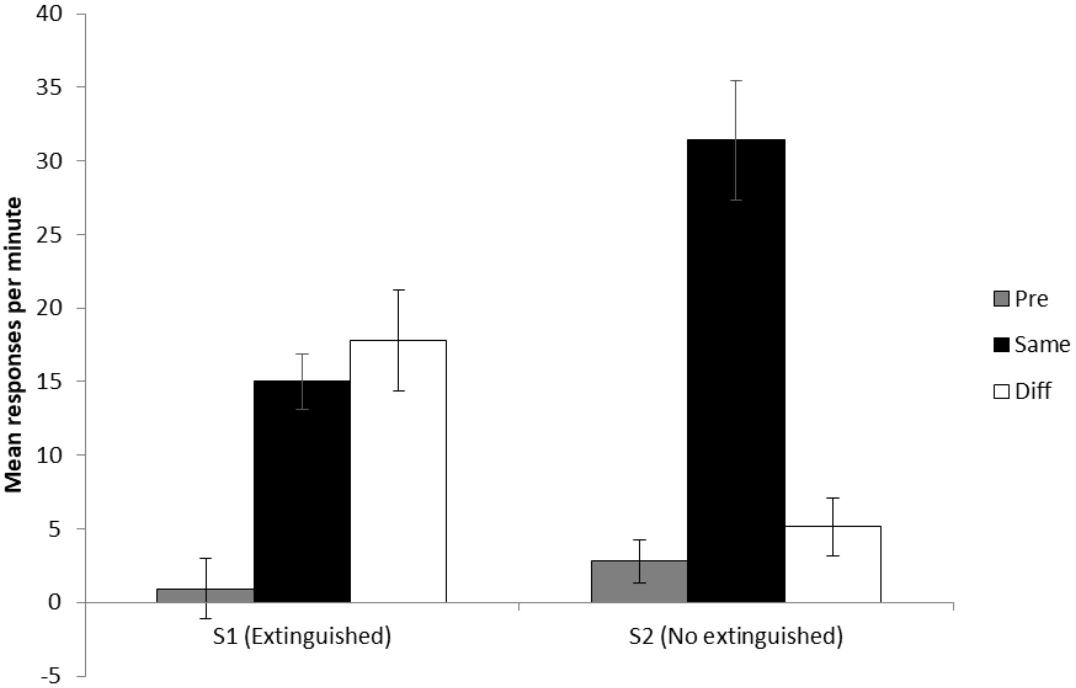

Figure 4. Mean response rate per minute in the absence (Pre) and in the presence of discriminative stimuli S1 and S2 during S-O Test. Rates for the extinguished (S1) and no extinguished (S2) stimuli are presented when stimuli were present. Same refers to the response that shares the outcome with the discriminative stimulus presented on test (R3 when S1 is presented and R4 when S2 is presented). Diff refers to the alternative response (R4 when S1 is presented and R3 when S2 is presented). Error bars represent within-subject standard errors following Cousineau-Morey corrections.