

Short Title: LEARNED ASSOCIATIONS

Associations in Human Instrumental Conditioning

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Abstract

Four experiments were conducted to study the contents of human instrumental conditioning. Experiment 1 found a positive transfer between a discriminative stimulus (S^D) and an instrumental response (R) that shared the outcome (O) with the response that was originally trained with the S^D , showing the formation of a $S^D \rightarrow O$ association. Experiment 2 found that post-acquisition devaluation of an outcome selectively reduced the response trained with that outcome, showing the formation of a $R \rightarrow O$ association. In Experiment 3, changing the outcome did not prevent participants from giving the response learned with each S^D , even though none of the responses was appropriate for the new outcome, showing evidence of the formation of $S^D \rightarrow R$ associations in instrumental learning. The three binary associations were shown within the same basic experimental situation. Finally, Experiment 4 found evidence of the formation of the higher order association $S^D(R \rightarrow O)$ in human instrumental conditioning.

Key-words: Instrumental conditioning, Contents of learning, Human learning, Associative learning.

Associations in Human Instrumental Conditioning

The study of the contents of instrumental learning refers to the study of the different associations that may be established among the three elements involved in an instrumental learning situation, that is, discriminative stimulus (S^D), instrumental response (R) and outcome (O). Different theoretical and experimental approaches to this issue can be found in the literature.

First, according to authors like Thorndike (1932) or Hull (1943), instrumental conditioning may be explained by the formation of $S^D \rightarrow R$ association, where the reinforcer or outcome (O) acts to enable the formation of the association, without taking direct part in it. Colwill (1994) found experimental evidence of the formation of this association in instrumental conditioning. She trained rats to perform two different responses (R1 and R2) in the presence of two different discriminative stimuli (A and B) to obtain food pellets (O1). Subsequently, two new responses (R3 and R4) were trained with 2 new reinforcers (O2 and O3) in the absence of a discriminative stimulus. Then R1 and R2 were trained with O2 and O3, respectively. Finally, during the test, R3 and R4 were tested in the presence of A and B. Colwill expected that the S^D would elevate the new response that shared the outcome with the response originally trained with the stimulus, even though such an outcome was never trained in the presence of the S^D . Thus, results could not be explained as caused by an $S^D \rightarrow O$ association. It was found that A elevated R3 while B elevated R4. In agreement with her hypothesis, this selectivity reflects the association between the discriminative stimulus and the instrumental response in the rat.

Second, it has been also found that $S^D \rightarrow O$ associations play a role in instrumental conditioning (e.g., Colwill & Rescorla, 1988; Gámez & Rosas, 2005). According to the two-process theory, during instrumental learning the formation of an association

between the stimulus and the response is accompanied by the formation of a Pavlovian association between the stimulus and the outcome that reinforces the response (Rescorla & Solomon, 1967; Trapold & Overmier, 1972). Colwill and Rescorla (1988) showed the formation of this association in instrumental conditioning by using what has been called the transfer technique. They trained rats with two different responses (R1 and R2) that were followed by two different outcomes (O1 and O2) in the presence of two different discriminative stimuli (A and B). Then they trained two new responses (R3 and R4), each followed by one of the two previously trained outcomes in the absence of discriminative stimuli. By the end of training both R1 and R3 had been followed by O1, and both R2 and R4 had been followed by O2. During the test, rats had the choice of making R3 or R4 in the presence of A and B. Each discriminative stimulus selectively increased the response with which it shared the reinforcer, and not the alternate one. This transfer of control between the discriminative stimulus and the instrumental response separately trained with the same outcome suggests that $S^D \rightarrow O$ associations play a role in instrumental conditioning.

Third, some authors have shown that $R \rightarrow O$ associations play an important role in instrumental conditioning (e.g., Colwill & Rescorla, 1986; Tolman, 1932). The typically used procedure to demonstrate the implication of this association in instrumental conditioning consists on changing the value of the reinforcer once training of the instrumental response has finished. Colwill and Rescorla (1985) conducted an experiment in which they devalued one of two reinforcers that had followed two different instrumental responses by pairing the reinforcer with gastric malaise. In a subsequent test, they found that rats preferentially performed the response that had been followed by the outcome that had not been devalued, showing that at least part of what

is learned in an instrumental learning situation is an association between the response and the outcome (e.g., Colwill & Rescorla, 1986; see also Vega, Vila, & Rosas, 2004).

Finally, authors like Skinner (1938) or Rescorla (1991) suggest that instrumental conditioning cannot be restricted to the binary associations described above. At least in some cases, instrumental conditioning includes the formation of a higher order association $S^D(R \rightarrow O)$ in which the association between the response and the outcome depends on the presence of the discriminative stimulus. To show the role of that association in instrumental conditioning, Colwill and Rescorla (1990) trained rats to perform two different responses (R1 and R2) to obtain two different reinforcers (O1 and O2) in the presence of one discriminative stimulus (A), while the opposite relationships (R1-O2 and R2-O1) were trained in the presence of an alternate discriminative stimulus (B). One of the reinforcers was devalued following this training. Finally, a test was conducted where both responses were available at the same time. Rats preferentially chose the response that had been followed by the non-devalued outcome in the presence of the discriminative stimulus. That is, the response chosen depended on the S^D present at the moment, suggesting that rats had learned a higher order association where the outcome that follows a response depends on the S^D .

Colwill (1994) suggests that the three binary and the higher order associations are concurrently established in nonhuman instrumental conditioning. With respect to human instrumental learning, most of the research refers to causal and contingency judgments focusing on the mechanisms and the conditions necessary for the development of human instrumental learning (e.g., Dickinson, 2001; Shanks, 1993). The number of studies that have been conducted with the aim of studying the contents of human instrumental learning from the associative point of view is smaller, and none of them

have conducted a complete analysis of the associative structure that potentially underlies human instrumental learning.

In one of those studies, Vega et al. (2004) conducted two experiments where the implication of the $R \rightarrow O$ association in human instrumental conditioning was evaluated using the outcome devaluation procedure developed by Rozeboom (1957). Participants were trained in a videogame war situation where they had to perform two different responses that were followed by two different outcomes (weapons) in the presence of two different discriminative stimuli. The value of one of the outcomes was subsequently devalued (Experiment 1) or inflated (Experiment 2) by an instruction that informed participants that one of the weapons (the weapons were the outcomes) either “does not work anymore” (Experiment 1) or “is now more powerful” (Experiment 2). Finally, during the test phase participants had the opportunity of perform both instrumental responses in the presence of each S^D . In agreement with the results previously found in non human animals (e.g., Colwill & Rescorla, 1985), Vega et al. (2004) found that the change in the value of the outcome differentially affected the instrumental response associated with the modified outcome.

In a recent study conducted in our laboratory, Gámez and Rosas (2005) used a transfer technique based in the one designed by Paredes-Olay, Abad, Gámez and Rosas (2002) with the goal of exploring the formation of $S^D \rightarrow O$ associations in human instrumental conditioning. In this procedure, participants are trained within a videogame situation where they are in charge of defending Andalucía from ship, tank and plane attacks. The defence is organized so that participants have to press different keys on a standard keyboard to destroy different attackers. With this procedure, Gámez and Rosas (2005) found acquisition and extinction of a human instrumental response. On exploring the formation of $S^D \rightarrow O$ associations with this procedure, participants were initially

trained to perform two instrumental responses (R1 and R2), each followed by a different outcome (O1 and O2). Subsequently, two new responses (R3 and R4) were followed by O1 and O2, respectively, each trained in the presence of one out of two different S^D (A or B). During the final test, participants had the opportunity to choose again between performing R1 and R2 in the presence and in the absence of each S^D (A or B). Similarly to what has been found in non human animals, participants preferentially chose R1 in the presence of A, and R2 in the presence of B. In other words, participants chose the response that had shared the outcome with the S^D , even though stimulus and response were never presented together before (see e.g., Colwill & Rescorla, 1988).

Part of the contents of instrumental learning both in human and nonhuman animals has been indirectly explored in the studies conducted with the differential-outcome procedure (e.g., Dube & McIlvane, 1995; Estévez, Overmier, & Fuentes, 2003; Rescorla & Colwill, 1989; Urcuioli, DeMarse, & Lionello-DeNolf, 2001). In a standard differential-outcome procedure, performance is better when two different S^D -R combinations are each followed by a specific outcome, than when both are followed either by the same outcome, or by both of them presented in a random alternation. This effect has been also found in children (e.g., Maki, Overmier, Delos, & Gutmann, 1995) and suggests that participants in these procedures use both $S^D \rightarrow O$ and $R \rightarrow O$ associations to solve the instrumental task (e.g., Rescorla, 1992; Rescorla & Colwill, 1989; Urcuioli & Demarse, 1996; Urcuioli et al., 2001)

Thus, human studies about the contents of human instrumental learning conducted so far have shown the role of the $R \rightarrow O$ and $S^D \rightarrow O$ binary associations. Our goal in the present experimental series is to explore the role of each of the associations possibly developed during human instrumental learning, including the exploration of the $S^D \rightarrow R$ binary association and the $S^D(R \rightarrow O)$ higher order association. To conduct this

exploration we have adapted the procedure used by Gámez & Rosas (2005) described above.

Four experiments were conducted. Experiment 1 evaluated the presence of $S^D \rightarrow O$ associations by using a transfer technique. Experiment 2 evaluated the presence of $R \rightarrow O$ associations by using a reinforcer devaluation procedure. Finally, the goals of Experiments 3 and 4 were to explore the presence of $S^D \rightarrow R$ and $S^D(R \rightarrow O)$ associations in human instrumental learning, respectively.

Experiment 1

As mentioned above, Gámez and Rosas (2005) conducted one of the studies that revealed that $S^D \rightarrow O$ associations may play a role in human instrumental conditioning. As the basic procedure used by Gámez and Rosas (2005) will be used in this experimental series, the main goal of Experiment 1 was to replicate the demonstration of this association in a situation where the other binary associations will be subsequently explored.

The design of the experiment is presented in Table 1. Two instrumental responses were followed by two different outcomes (R1-O1 and R2-O2). Subsequently, two different responses were followed by the same outcomes previously used (R3-O1 and R4-O2). During discriminative training, R3 was trained with O1 in the presence of A, and R4 was trained with O2 in the presence of B. Finally, a test in extinction was conducted where participants had the opportunity of responding in R1 and R2 alternatives in the presence of the two discriminative stimuli that were previously trained with R3 and R4. According to what has been found in the animal (e.g., Colwill & Rescorla, 1988) and human literature (e.g., Gámez & Rosas, 2005), we expected participants to preferentially chose R1 in the presence of A and R2 in the presence of B.

In other words, we expected participants to choose the response that was trained with the same outcome that was trained with the present stimulus.

 INSERT TABLE 1

Method

Participants

Participants were 8 undergraduate students from the University of Jaén between 18 and 25 years, naïve to the task, and they received course credit for participation. In this and the following experiments, approximately 75% of the participants 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 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 I, M, F and J were used as responses. These keys were covered with coloured stickers. Green and orange stickers were counterbalanced as R1 and R2, and white and black stickers were counterbalanced as R3 and R4. 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 on successive screens (800 x 600 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 you for 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 people. If you wish to participate in the experiment, we would ask you 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 1. 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-boat torpedoes. Your mission consists of destroying the ships and the planes before they reach 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 on 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 on one of the monitors within the screen. Correct responses were reinforced under a variable interval reinforcement schedule with a mean of 2 s and a range between 1 and 4 s (VI2). Each trial lasted 4 sec.

Response training 2. 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 began after the following instructions:

“(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 you do not have any doubts, press B to continue. Good luck!”

Instructions were followed with twelve A:R3-O1 and 12 B:R4-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 VI2 reinforcement schedule.

Transfer test. The test began with the following message:

“We have trouble; your weapons are failing again. During this period we have fixed your original weapons (ORANGE and GREEN keys). So, you should use them to destroy ships and planes from now on (press the B key to continue)”.

Two test trials with each discriminative stimulus were presented in extinction while participants were responding on R1 and R2. Aside for the use of different responses and the lack of reinforcement, these trials were identical to the ones used during the discriminative training phase. Trial order was fully counterbalanced both within and between participants.

Dependent variable and statistical analysis

Responses per minute were recorded in each phase of the experiment in this and the rest of the experiments that form this series. Responding was evaluated by analysis of variance (ANOVA). The rejection criterion was set at $p < .05$.

Results and discussion

Acquisition proceeded uneventfully, with similar results to the ones reported by Gámez and Rosas (2005). In the last 3-trial block of discriminative training mean response rate for R3 and R4 was, respectively, 0.94 (0.94) and 0.00 (0.00) in the absence of the discriminative stimulus (Pre), and 225.00 (31.59) and 216.56 (24.53) in the presence of the stimulus. A 2 (Response) x 2 (Stimulus) only found a significant main effect of Stimulus, $F(1, 7) = 80.89$, (MSe = 388300.781), revealing a higher rate of responding in the presence of the discriminative stimulus than in its absence (pre) regardless of the response. Neither the main effect of Response, nor the Stimulus x Response interaction were significant, $F_s < 1$.

Figure 1 presents response rate during the Pre and the Stimulus periods during the test, with the response that shared the same (Same) or different (Different) outcome with the discriminative stimulus. The figure shows that the discriminative stimulus transferred control (response rate higher in Same than in Different) to the responses with which it shared the reinforcer when the stimulus was present. A 2 (Stimulus, Pre vs. stimulus) x 2 (Transfer, same vs. different) ANOVA found a significant main effect of Stimulus, $F(1, 7) = 24.76$ (MSe = 20884.57), and Transfer, $F(1, 7) = 24.97$ (MSe = 39025.19). Most important, a significant Stimulus x Transfer interaction was found, $F(1, 7) = 14.84$ (MSe = 29251.76).

 INSERT FIGURE 1

Subsequent analysis conducted to explore the Stimulus x Transfer interaction found that the simple effect of transfer was significant in the presence of the stimulus, $F(1, 7) = 21.51$ (MSe = 67925.39), but not during the Pre period, $F < 1$.

In the absence of the discriminative stimulus, there were no differences in the response rate across different response alternatives. However, when the stimulus was on, participants preferentially chose the response alternative that shared the outcome with the present stimulus. This transfer effect seems to support the importance of $S^D \rightarrow O$ association in instrumental conditioning in full agreement with the results previously found in non-human animals (e.g., Colwill & Rescorla, 1988), and replicates the findings previously reported from our laboratory (Gámez & Rosas, 2005; see also Paredes-Olay et al., 2002, for related results in human predictive learning).

It should be noted that response training during the initial stages of the experiment was conducted in the presence of the enemy whose destruction constituted

the outcome. This enemy could have become the discriminative stimulus for the specific response the participant should give in that situation, in the same sense that the lever or the chain could become a discriminative stimulus for the response the rat has to give to obtain the reinforcer in animal conditioning experiments, where responses are usually trained in separate sessions in the initial stages of the experiment. The reason to conduct the experiment this way was to simplify the acquisition of the response-outcome relationships. Note that after discriminative training both stimuli (both enemies) were presented together and thus, their value as discriminative stimuli for the response was lost after response training, and does not preclude the interpretation of the results in terms of $S^D \rightarrow O$ associations.

However, the presence of the enemy as a discriminative stimulus could have facilitated the formation of a mediated association between R1 and R3, and between R2 and R4. In other words, response equivalence may have been established between R1 and R3, and between R2 and R4, via the common outcomes that these responses shared. If that were the case, then the results of this experiment could be revealing the formation of $S^D \rightarrow R$ associations during instrumental training, an interpretation that could be also applied to previous results in the literature that use the transfer technique to evaluate $S^D \rightarrow O$ associations (see for instance Colwill & Rescorla, 1988; Gámez & Rosas, 2005).

Note that the interpretation of these results in terms of $S^D \rightarrow R$ associations require of the assumption of additional mediated $R \rightarrow R$ associations, suggesting that the simpler $S^D \rightarrow O$ interpretation of transfer results may be more parsimonious at this point.

Experiment 2

Aside from the $S^D \rightarrow O$ association suggested by the data reported by Gámez and Rosas (2005) in human beings and replicated in Experiment 1, another association that has been shown in human instrumental conditioning is the one established between the

response and the outcome (e.g., Estévez et al., 2003). In an specific evaluation of the role of this association in human instrumental learning, Vega et al. (2004) conducted two experiments where the value of the reinforcer was modified after training, and found that this modification was accompanied by changes in the rate of the response associated with the outcome.

The goal of Experiment 2 was to replicate the results obtained by Vega et al. (2004) with the same situation and the same basic design used in Experiment 1, so that the possibility of $R \rightarrow O$ association in human instrumental conditioning can be tested in the same situation where the implication of $S^D \rightarrow O$ associations has already been suggested.

The design of the experiment is presented in Table 2. Two groups of participants were trained first with two different R-O relationships. This training was followed by a discriminative training phase where each of those relationships was only in effect in the presence of a specific S^D . Finally, a test in extinction was conducted in the presence of each S^D . Groups differed in the treatment received during the devaluation phase prior the test. In the Experimental group one of the outcomes was devalued by presenting an instruction that indicated that one of the attackers was now indestructible. In the Control group the devalued outcome was one that was never presented before (O3, tanks are now indestructible). During the test, it was expected that participants would preferentially chose the response that had been followed by a non devalued outcome than the one that was followed by the devalued outcome in the Experimental group. No differences were expected in the Control group.

 INSERT TABLE 2

Method

Participants and apparatus

Sixteen students participated in the experiment. Except where noted, participants and apparatus were identical to the ones used in Experiment 1. As only two responses were required in this experiment, F and J keys were covered with green and orange stickers and counterbalanced as R1 and R2.

Procedure

Participants were assigned randomly to Experimental and Control groups upon their arrival at the laboratory. Except where noted, the procedure was identical to the one described in Experiment 1 (see Table 2). No training with R3 and R4 was conducted. The discriminative training phase was conducted only with R1 and R2. So that O1 was provided when R1 was performed in the presence of A and O2 was provided when R2 was performed in the presence of B.

Devaluation phase. This was the only phase where Experimental and Control groups differed. Participants in the Control group received the following instruction:

“WARNING!! Attackers have been reinforced with TANKS that are indestructible. TANKS are indestructible!! (press B key to continue)”.

This instruction did not devalue any of the previously presented outcomes because no tanks were presented throughout training. Participants in the Experimental group received one of the following instructions (half of them received the first instruction, and the other half received the second one):

“WARNING!! Attackers have reinforced their PLANES with anti-missile shields that make them indestructible. PLANES are now indestructible!! (press B key to continue)”.

“WARNING!! Attackers have reinforced their SHIPS with anti-missile shields that make them indestructible. SHIPS are now indestructible!! (press B key to continue)”.

These instructions devalued one of the outcomes presented during the discriminative training phase. For half of the participants, the missile was devalued; for the other half the devalued outcome was the torpedo.

Test. Immediately after a participant finished reading the devaluation instruction, the test began. During the test, one trial with each discriminative stimulus was conducted. Trials were identical to the ones conducted during the discriminative training phase, with the exception that no reinforcement was presented. A single test trial was conducted in this and the following experiments because, contrary to what was found in Experiment 1, pilot experiments had shown that carry-over effects of first trial clearly affected performance in the second trial in this procedure (usually, once participants see the inefficacy of their response in the first test trial they perform the alternate response in the second trial, wiping the differences up).

Results and discussion

Acquisition proceeded uneventfully. In the Experimental group, mean rate of responding in the last 3-trial block of training to the response alternative whose outcome was subsequently going to be devalued and to the non-devalued outcome response alternative was, respectively, 0.94 (0.94) and 0.94 (0.94) in the absence of the S^D (Pre), and 157.50 (23.37) and 127.50 (21.21) in the presence of the S^D (Stimulus). In the Control group, mean rate of responding in the last 3-trial block of training to the response alternative to be followed by the devalued outcome and to the response to be followed by the non-devalued outcome was, respectively, 0.94 (0.94) and 0.00 (0.00) during the absence of the stimulus (Pre), and 159.37 (28.76) and 166.87 (29.45) in the presence of the S^D . Standard errors are presented within brackets. Note that in the Control group no trained outcome was actually devalued. Thus, to assign the devalued label in this group, each subject was yoked to an equivalent participant in the

Experimental group. That is, if for participant number 1 in the Experimental group the devalued outcome was the missile, the same was true for participant number 1 in the Control group. A 2 (Group) x 2 (Outcome) x 2 (Stimulus) ANOVA found a significant main effect of stimulus, $F(1, 15) = 80.44$ ($MSe = 370196.19$). No other effect or interaction was significant, $F_s < 1$. Thus, performance at the end of training depended on whether the discriminative stimulus was present or not, regardless of the group or the outcome.

 INSERT FIGURE 2

Figure 2 presents response rate during the discriminative stimulus in the response alternative that had the devalued outcome and the response alternative that did not have the devalued outcome in the Experimental and Control groups at the final test. A 2 (Group) x 2 (Outcome) ANOVA found a significant main effect of Group, $F(1, 15) = 8.28$ ($MSe = 83538.28$), and Outcome, $F(1, 15) = 12.56$ ($MSe = 37469.53$). Most important, there was a significant Group x Outcome interaction, $F(1, 15) = 16.23$ ($MSe = 48438.28$).

Subsequent analyses conducted to explore the Group x Outcome interaction found that the simple effect of Outcome was significant in the Experimental group, $F(1, 15) = 19.32$ ($MSe = 85556.25$), but was not in the Control group, $F < 1$. Participants in the Experimental group preferentially chose the response alternative that had been followed by an outcome that was not devalued, rather than the response alternative that had been followed by the devalued outcome. There were no differences in responding in the Control group where the devalued outcome was not an outcome paired with the trained responses.

Finally, mean rate of responding during the Pre period was 0.00 for every condition except for the non-devalued outcome in the Control group that was 5.63 (3.94). A 2 (Group) x 2 (Outcome) ANOVA did not find any significant main effects or interaction between them, $F_s < 1$.

Thus, a decrease in the value of the outcome instructionally induced produces an important and selective decrease in the rate of responding in the response alternative paired with the devalued outcome, providing evidence about the role of the $R \rightarrow O$ association in instrumental conditioning and replicating the results previously found in nonhuman animals, (e.g., Colwill & Rescorla, 1985) and human beings (Vega et al., 2004).

The design of Experiment 2 allows for an alternative interpretation in terms of the formation of $S^D \rightarrow O$ associations. Note that devaluation of O should affect both, $S^D \rightarrow O$ and R-O associations. Thus, part of the loss of responding by the devaluation procedure could be due to the loss of response support provided by the $S^D \rightarrow O$ association. However, it is unlikely that the break of the $S^D \rightarrow O$ association fully explains the complete loss of responding found in this experiment without making reference to the R-O association. This interpretation is prompted by the use of a discriminative stimulus in this specific design. The use of a S^D was justified by the need of testing the different associations within the same experimental situation. However, an unpublished experiment conducted in our laboratory that used the exact same design but in the absence of discriminative stimulus found the same results reported here in a situation where no $S^D \rightarrow O$ associations could explain performance at testing. Given the identical result regardless of the presence or the absence of the S^D , it seems unlikely that the results of the present experiments could be fully explained without referring to the formation of $R \rightarrow O$ associations.

Experiment 3

Experiments 1 and 2 suggest the presence of $S^D \rightarrow O$ and $R \rightarrow O$ associations in an instrumental learning situation in human beings, reporting similar results to the ones previously found in animals (e.g., Colwill & Rescorla, 1985, 1988) and humans (e.g., Gámez & Rosas, 2005; Vega et al., 2004).

However, different experiments conducted with nonhuman animals have indirectly shown a third binary association in instrumental performance, the $S^D \rightarrow R$ association. For instance, outcome devaluation does not usually have a full effect, often leaving some residual responding that is usually attributed to the $S^D \rightarrow R$ association that should not be affected by outcome devaluation (but see Experiment 2 above). Colwill (1994) was the first author to obtain direct evidence of the role of the $S^D \rightarrow R$ association in instrumental performance in nonhuman animals by using the transfer technique described in the general introduction.

Given the lack of studies exploring the role of $S^D \rightarrow R$ associations in human instrumental conditioning, the main goal of this experiment was to test whether such an association would play a role in instrumental performance within a situation where the other two binary associations were already shown in Experiments 1 and 2. The design of the experiment is presented in Table 3. Two instrumental responses (R1 and R2) were followed by the same outcome in the presence of two different discriminative stimuli. That is, each discriminative stimulus indicated that destruction of one of two possible enemies was possible by giving the appropriate response. During the test, participants had the opportunity to make either of the two trained responses in the presence of each of the two discriminative stimuli. However, the enemy at testing was different from the enemy that was presented during the acquisition phase. As the enemy was new during the test phase, there was no reason to show a preference for the use of

either of the two trained responses, except for the presence of the discriminative stimulus. Thus, if the $S^D \rightarrow R$ association plays a role in this instrumental conditioning situation, it would be shown as a preference for performing the response that was originally reinforced under the present S^D rather than the response that was reinforced under the alternate S^D .

 INSERT TABLE 3

Method

Participants and apparatus

Eight students participated in the experiment. Except where noted, participants and apparatus were identical to the ones used in Experiment 2.

Procedure

Except where noted, the procedure was identical to the one described in Experiment 1 (see Table 3). No training with R3 and R4 was conducted. The discriminative training phase was conducted with only R1 and R2.

Discriminative training. In this experiment no previous response training was conducted. Thus, instructions prior training included a combination of the response and discriminative training described above. Accordingly, the first two instruction screens were followed by the instructions described in the discriminative training of Experiment 1, beginning in the sentence “Your weapons have a reaching range of 500 meters.”

Fifteen trials with each discriminative stimulus (A and B) were conducted. The same enemy was presented on every trial (either the plane or the ship, counterbalanced) and responses (R1 or R2) were followed by reinforcement depending on the S^D . To facilitate the response discrimination, the S^D was on for 16 s during the first set of 5

trials, for 8 s during the second set of 5 trials, and for the standard 4 s during the final set of 5 trials.

Test. This phase began right after discriminative training ended, without any indication to the participant. One trial with each S^D was conducted in extinction. In a given trial, the S^D appeared accompanied by an enemy that was different from the one that was presented during acquisition.

Results and Discussion

Response rate in the last 3-trial block of acquisition was 206.25 (29.72) and 196.25 (34.18) in the presence of stimuli A and B, respectively. There were no significant differences between the two response rates, $F < 1$.

Figure 3 presents the response rate during the test separated as a function of whether the response is the same that was appropriate to the S^D during the acquisition phase (Same) or the alternate response (Different). Response rate in the Same alternative was significantly higher than in the Different alternative, $F(1, 7) = 67.76$ ($MSe = 58503.55$).

 INSERT FIGURE 3

Participants' response to the new enemy was similar to participants' response to the enemy originally trained with the present S^D . Given that in this situation the only possible guide for choosing a response to confront the new enemy was the presence of the discriminative stimulus, choosing the Same response implies the presence of a S^D -R association. Finding evidence of an S^D -R association in this situation is particularly interesting. Notice that the cover story required the participant to discriminate between which key fired anti-aircraft missiles and which key fired anti-boat torpedoes. From the

logic of the story, the change of the enemy during the test should lead participants to conclude that no weapon would be useful at that point –for instance, no destruction of planes will be expected by firing anti-boats torpedoes. From a rational point of view, no response was expected at testing. However, response was differentially made as a function of the discriminative stimulus, and the rate of response seemed to be almost as high as the rate given at the end of discriminative training.

These results are in agreement with the ones reported by Colwill (1994) with nonhuman animals and complete the analysis of the role of binary associations in a human instrumental learning situation.

Experiment 4

Experiments 1 to 3 revealed that all three binary associations that may be formed among the three elements involved in instrumental conditioning (S^D , R and O) can be found within instrumental learning situations that are quite alike. Skinner (1938) suggested that the contents of instrumental learning cannot be understood without including the study of the role of a higher order association among the three elements involved in instrumental conditioning, the $S^D(R \rightarrow O)$ association (see also Colwill & Rescorla, 1990; Rescorla, 1991). Unequivocal evidence of the role of that association in nonhuman animals is scarce, and it is absent in human instrumental conditioning. For instance, Colwill and Rescorla (1990, Experiment 2) trained a group of rats with two different responses (R1 and R2) that were followed by two different outcomes (O1 and O2) in the presence of two discriminative stimuli (A and B). Response-outcome relationships were reversed as a function of the present S^D . If stimulus A was present, then R1 was reinforced with O1 and R2 was reinforced with O2, and the contrary was true when stimulus B was present. One of the outcomes was subsequently devalued. Colwill and Rescorla (1990) found that the response that was affected by the outcome

devaluation depended on the S^D present, a result that suggests that rats formed a higher order relationship where the R-O association depended on the S^D .

The goal of this Experiment was to evaluate the presence of the $S^D(R \rightarrow O)$ association in a human instrumental learning situation by using the experimental design presented in Table 4, that was akin to the one used by Colwill and Rescorla (1990). Two different responses (R1 and R2) were followed by two different outcomes (O1 and O2) in a discrimination that reversed depending on the presence of two different discriminative stimuli (A and B). One of the outcomes was subsequently devalued before a test in extinction. In this design, discriminative stimuli are equally related to both responses and both outcomes as independent elements but they announce unique R-O associations. Thus, we expected devaluation to differentially affect responding depending on the discriminative stimulus. That is, if O1 is devalued then the rate of responding in R1 should be lower than in R2 in the presence of A, and the contrary should be true in the presence of B.

 INSERT TABLE 4

Method

Participants and apparatus

Eight students participated in the experiment. Except where noted, participants and apparatus were identical to the ones used in Experiment 2.

Procedure

Except where noted, procedure was identical to the one described in Experiment 3 (see Table 4).

Discriminative training. Thirty trials with each discriminative stimulus (A and B) were conducted. In each of those trials, a single attacker was presented (either the ship or the plane) and making the appropriate response provided the reinforcer on our standard VI2 reinforcement schedule. In order to facilitate acquisition of the instrumental response, the duration of the S^D in the first 10 trials was 16 s, the S^D in the second block of 10 trials was 8 seconds, and finally, the last 10-trial block was conducted with our standard 4 s trials.

Devaluation. Participants received one of the following instructions (half of them received the first instruction, and the other half received the second one):

“WARNING!! Enemy troops have regrouped (now ships and planes will attack together) and they reinforced their PLANES with anti-missile shields that make them indestructible. PLANES are now indestructible. The battle continues!! (press B key to continue)”.

“WARNING!! Enemy troops have regrouped (now ships and planes will attack together) and they reinforced their SHIPS with anti-torpedo shields that make them indestructible. SHIPS are now indestructible. The battle continues!! (press B key to continue)”.

Test. Immediately after the participant finished reading the devaluation instruction the test began. During the test, one trial with each discriminative stimulus was conducted. Trials were identical to the ones conducted during the last block of trials of the discriminative training phase with the exception that no reinforcement was presented and that both attackers were presented at the same time.

Results and Discussion

Response rate in the last 3-trial block of acquisition in the presence of A was 172.44 (24.85) and 188.68 (26.12) for the response that was followed by the subsequently devalued outcome and for the response that was followed by the non-devalued outcome, respectively. In the presence of B response rate was 201.86 (19.38) and 169.97 (22.00) for devalued and non-devalued outcome, respectively. Standard

errors of the mean are presented within brackets. A 2 (Stimulus) x 2 (Outcome) ANOVA did not find significant main effects or interaction between them, largest $F(1, 7) = 4.15$ ($MSe = 995.56$).

Figure 4 presents the mean response rate in the alternative that was followed by the devalued outcome and the response alternative that was followed by the non-devalued outcome in the presence of each S^D in the final test of Experiment 4. A 2 (Stimulus) x 2 (Outcome) ANOVA found a significant main effect of Outcome, $F(1, 7) = 52.05$ ($MSe = 168925.78$). Most important, neither the main effect of Stimulus, nor the Stimulus x Outcome interaction were significant, largest $F(1, 7) = 1.84$ ($MSe = 95.42$). That is, when the two attackers appeared in the presence of a specific S^D , participants chose preferentially to make the response that had been followed by the non-devalued outcome. Interestingly, this response varied depending on the present S^D (if they chose R1 in the presence of A, they then chose R2 in the presence of B).

 INSERT FIGURE 4

The design of the experiment precludes interpretation of these results as caused by an $S^D \rightarrow O$ binary association, given that both outcomes are presented with the same frequency in the presence of both discriminative stimuli. A similar problem would be raised while trying to explain these results as based on $S^D \rightarrow R$ or $R \rightarrow O$ associations, given that first, the S^D is equally related to both responses, and second, that both R are equally related to both outcomes. Therefore, these results suggest that human beings use $S^D(R \rightarrow O)$ associations to solve instrumental conditioning discriminations, as has been previously shown in rats (Colwill & Rescorla, 1990).

However, there is an alternative explanation for these results that should be at least considered. If one were to assume that participants make a configuration between the S^D and each response that would be specifically paired with the outcome, then the results of this experiment would be showing evidence of associations between the $S^D R$ compound and the outcome (see e.g. Urcuioli et al., 2001). Thus, being conservative, this experiment allows concluding that participants may take in account all the elements involved in the instrumental conditioning situation at the same time. Whether these three elements are combined in a hierarchical association (e.g., Colwill & Rescorla, 1990; Skinner, 1938) or in different configurations including the various $S^D R$ combinations that are associated with each specific outcome is something that should be explored in further experiments.

General Discussion

This experimental series was conducted with the aim of exploring the contents of human instrumental learning, searching for the four possible associations that might be formed in human instrumental conditioning [$S^D \rightarrow O$, $S^D \rightarrow R$, $R \rightarrow O$, and $S^D(R \rightarrow O)$]. Four experiments were conducted where devaluation and transfer procedures were used, and experimental evidence was found for the role of each of association in human instrumental learning.

Experiment 1 was conducted to evaluate the role of a $S^D \rightarrow O$ association in human instrumental conditioning by using a transfer technique. The results obtained were similar to the ones usually found in both the animal (e.g., Colwill & Rescorla, 1988) and human literatures (e.g., Gámez & Rosas, 2005). A Stimulus-outcome based selective transfer was found so that participants preferentially chose the response alternative that shared the outcome with the discriminative stimulus even though that specific response was never trained in the presence of that discriminative stimulus (see

also Colwill & Rescorla, 1986; Paredes-Olay et al., 2002; but see discussion of Experiment 1 for an alternative account of these results in terms of $S^D \rightarrow R$ associations due to a hypothetical acquired equivalence between each pair of responses mediated by the common outcome).

Clear evidence of the role of the $R \rightarrow O$ association in human instrumental conditioning was found in Experiment 2 by using the outcome devaluation technique (see also Vega et al., 2004). Outcome devaluation selectively decreased the rate of responding in the response alternative that was previously trained with the devalued outcome, a result that can only be explained if participants had formed a $R \rightarrow O$ association during training (see also Colwill & Rescorla, 1985, 1986). As pointed out in the discussion of Experiment 2, part of this selective decrease could be due to the loss of support of the response by an $S^D \rightarrow O$ association that should also be affected by the outcome devaluation. However, as we have found equivalent results in an unpublished experiment where no S^D was used, this alternative account in terms of $S^D \rightarrow O$ associations does not seem enough to fully explain the results obtained in Experiment 2.

Experiment 3 evaluated the formation of an $S^D \rightarrow R$ association by changing the possible outcome with respect to the trained outcome. Participants in that situation kept performing the response that was learned in the presence of the discriminative stimulus, revealing that they had formed a $S^D \rightarrow R$ association during training (see also Colwill, 1994). The training situation in this experiment could be considered similar enough to the training conducted in Experiments 1 and 2 as to suggest that the three binary associations could be concurrent contributors to human instrumental performance in this situation.

Finally Experiment 4 found evidence of the presence of a higher order association in human instrumental learning, where the S^D served as a signal for the

R→O association. After reversing the R-O training depending on the S^D , devaluation of the outcome led to a decrease in the instrumental response that was followed by the devalued outcome, similar to the one found in Experiment 2. However, due to the reversal training, the response affected by the outcome devaluation changed depending on the S^D , revealing the formation of a higher order association in this situation (Colwill, 1994). As pointed out in the discussion of Experiment 4, this result could be also interpreted in terms of the formation of binary associations between a $S^D R$ configure and the outcome. At this point, the safest conclusion that can be made about the results of Experiment 4 is that participants are able to use all the information they receive at the same time to solve an instrumental learning problem, regardless of whether they are using a hierarchical or a configural solution for the instrumental situation.

Taking all the results reported in these studies together, it could be considered that the contents of human instrumental conditioning may be concurrently formed by three binary associations, $S^D \rightarrow O$, $R \rightarrow O$ and $S^D \rightarrow R$, and a higher order $S^D(R \rightarrow O)$ association. However, this conclusion might be premature. According to the results obtained in Experiments 1 to 3, there seem to be grounds to claim that the three binary associations might be concurrent contributors to human instrumental performance. This was not the same case in Experiment 4. The design of the last experiment included specific training on $S^D(R \rightarrow O)$ discriminations (or in $S^D R \rightarrow O$ discriminations), because the outcome of the response was different depending on the S^D . Thus, it might be claimed that higher order or configural associations need specific training to develop. To conclude that the four possible associations concurrently play a role in human instrumental conditioning, these associations should be concurrently shown within the

same basic experimental design. Unfortunately, there are not tools in the current literature that allow for such a test.

The approach that we have followed to explain the results presented in this paper is an associative one. However, most of these results could be potentially interpreted in terms of verbal reasoning, so that nonassociative processes could contribute to the results. As pointed out in the discussion of Experiment 3, this interpretation is unlikely for the results obtained in that experiment. Remember that performance according to the $S^D \rightarrow R$ association that was evident in that experiment was due to participants using missiles to destroy ships, and torpedoes to destroy planes, something that does not seem according to reason. Additionally, participants were regularly (albeit informally) questioned about their performance on the experiments right after they finished with the task. Their explicit knowledge about the contingencies of the experiment was quite poor in most cases. For example, every participant in Experiment 1 reported that his/her response had been distributed randomly between the two response alternatives during the transfer test regardless of whether the stimulus was present or not, when Figure 1 shows that random choice had little to do with their actual performance. Though this informal reports cannot be considered enough as to reject the contribution of verbal reasoning to the results, they seem enough as to suggest that the whole pattern of results reported in this article cannot be explained by solely verbal reasoning skills.

In summary, in a conservative conclusion, the results of these experiments provide suggest the independent formation of the four possible associations in human instrumental learning, and show important similarities to what has been found in nonhuman animal conditioning experiments (see Colwill, 1994).

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Table 1. Design of Experiment 1

R. T. 1	R. T. 2	Discrimination Training	Test
R1-O1	R3-O1	A: R3-O1	A: R1 vs. R2
R2-O2	R4-O2	B: R4-O2	B: R1 vs. R2

Note. R. T.: Response Training. A, and B were a red rectangle and a blue oval. R1, R2, R3 and R4: keys I, M, F, and J in a standard computer keyboard, respectively. Keys were covered by colored stickers; green and orange stickers were counterbalanced as R1 and R2, and white and black stickers were counterbalanced as R3 and R4. O1 and O2 were ship and plane destruction, counterbalanced. See text for details.

Table 2. Design of Experiment 2

Group	Response training	Discrimination Training	Devaluation	Test
Control	R1-O1	A: R1-O1	O3	A: R1 vs. R2
	R2-O2	B: R2-O2		B: R1 vs. R2
Experimental	R1-O1	A: R1-O1	O1 or O2	A: R1 vs. R2
	R2-O2	B: R2-O2		B: R1 vs. R2

Note. A, and B were a red rectangle and a blue oval. R1 and R2 were orange and green keys (F and J). O1 and O2 were ship and plane destruction during training, becoming indestructible during devaluation phase. O3 was the tank becoming indestructible. Stimuli, responses, and outcomes were counterbalanced across participants. See text for details.

Table 3. Design of Experiment 3

Discrimination training	Test
A: R1-O1	A: R1 vs. R2 (O2)
B: R2-O1	B: R1 vs. R2 (O2)

Note. A, and B were a red rectangle and a blue oval. R1 and R2 were the orange and the green keys (F and J). O1 & O2: ship and plane destruction. Stimuli, responses, and outcomes were counterbalanced across participants. The attacker (plane or ship) was changed between training and testing. No outcome was presented during the test (no destruction of the attackers). See text for details.

Table 4. Design of Experiment 4

Discrimination Training	Devaluation	Test
A: R1-O1, A: R2-O2	O1 or O2	A: R1 vs. R2
B: R1-O2, B: R2-O1		B: R1 vs. R2

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

Figure legends

Figure 1. Mean response rate per minute in the response alternative that shared the outcome with the present S^D (R1 in the presence of A, and R2 in the presence of B, labelled as Same) and in the response that did not shared the outcome with the present S^D (Different) in the Pre and the Stimulus periods during the test phase of Experiment 1. Error bars denote standard errors of the mean.

Figure 2. Mean response rate per minute in the presence of the S^D as a function of whether the outcome was previously devalued or not in the Control and Experimental groups during the test of Experiment 2. Error bars denote standard errors of the mean.

Figure 3. Mean response rate per minute in the presence of the S^D separated as a function of whether the response was the same as the one that was appropriate to the S^D during the acquisition phase (Same) or the alternate response (Different) in Experiment 3. Error bars denote standard errors of the mean.

Figure 4. Mean response rate in the response alternative that was followed by the devalued outcome and the response alternative that was followed by the non-devalued outcome in the presence of each S^D in the final test of Experiment 4. Error bars denote standard errors of the mean.

Figure 1

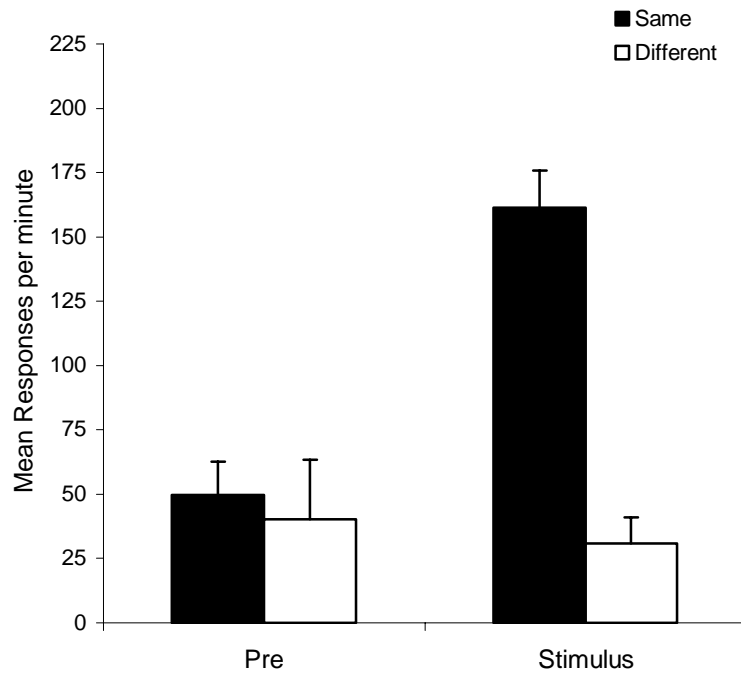


Figure 2

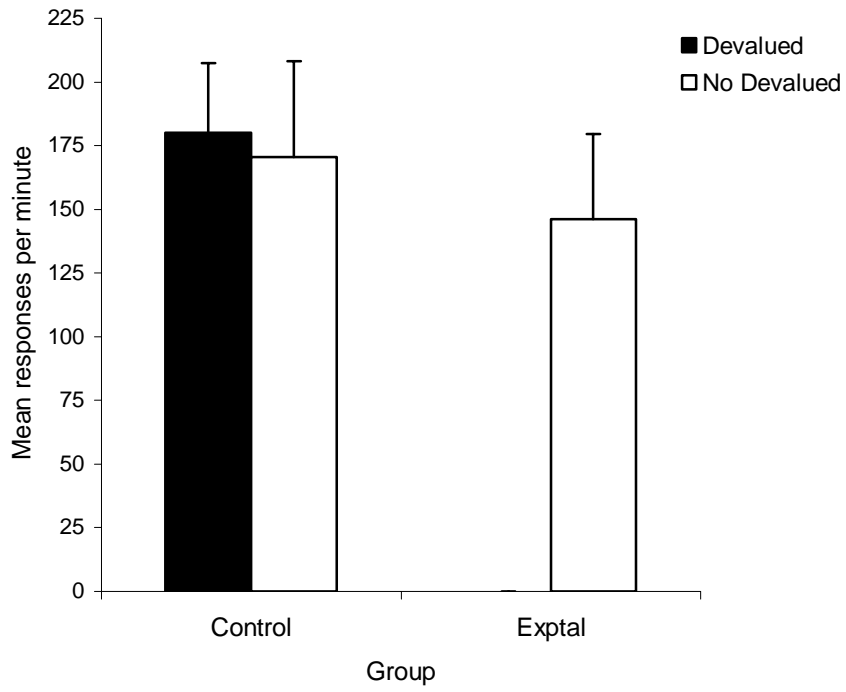


Figure 3

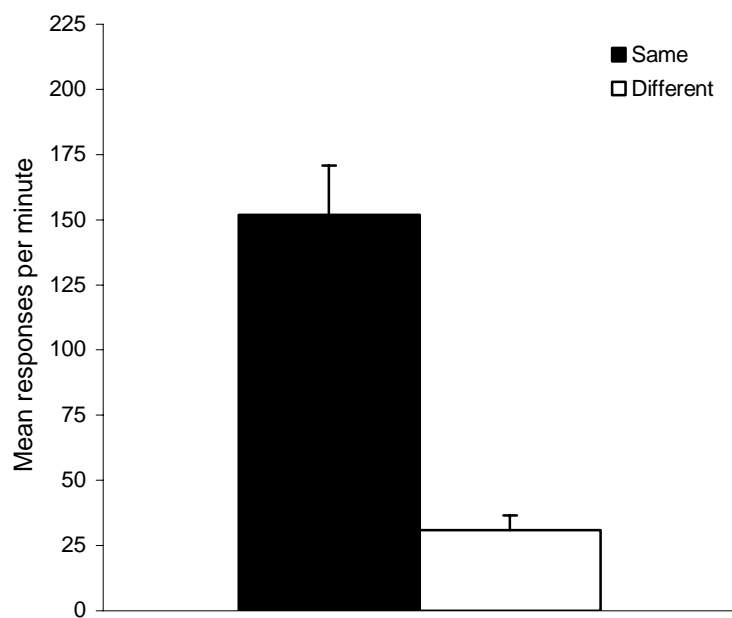


Figure 4

