Longitudinal investigation on learned helplessness tested under negative and positive reinforcement involving stimulus control

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A B S T R A C T
In this study, we investigated whether (a) animals demonstrating the learned helplessness effect during an escape contingency also show learning deficits under positive reinforcement contingencies involving stimulus control and (b) the exposure to positive reinforcement contingencies eliminates the learned helplessness effect under an escape contingency. Rats were initially exposed to controllable (C), uncontrollable (U) or no (N) shocks. After 24h, they were exposed to 60 escapable shocks delivered in a shuttlebox. In the following phase, we selected from each group the four subjects that presented the most typical group pattern: no escape learning (learned helplessness effect) in Group U and escape learning in Groups C and N. All subjects were then exposed to two phases, the (1) positive reinforcement for lever pressing under a multiple FR/Extinction schedule and (2) a re-test under negative reinforcement (escape). A fourth group (n = 4) was exposed only to the positive reinforcement sessions. All subjects showed discrimination learning under multiple schedule. In the escape re-test, the learned helplessness effect was maintained for three of the animals in Group U. These results suggest that the learned helplessness effect did not extend to discriminative behavior that is positively reinforced and that the learned helplessness effect did not revert for most subjects after exposure to positive reinforcement. We discuss some theoretical implications as related to learned helplessness as an effect restricted to aversive contingencies and to the absence of reversion after positive reinforcement. This article is part of a Special Issue entitled: insert SI title.

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Studies have produced evidence that subjects exposed to uncontrollable aversive stimuli have subsequent difficulty in learning new operant responses that are negatively reinforced. This effect has been termed learned helplessness (Maier and Seligman, 1976; Overmier and Seligman, 1967).
The learned helplessness effect has been suggested as an animal model of depression (Seligman, 1975). Among the many interpretations of the effect, the most disseminated one is that under an uncontrollable aversive condition, the subject learns that responses and the interruption of aversive stimuli are independent. Given that such independence is contrary to operant contingency, it will interfere with a new operant learning in a posterior test condition (Maier and Seligman, 1976; Maier et al., 1969; Peterson et al., 1993).
Some studies have suggested that this effect can be reversed, thereby forcing the animal to be exposed to operant reinforcement. For instance, Seligman et al. (1968) repeatedly forced helpless dogs to experience the escape contingency (being pulled by a belt). The consequence of the experience was that the animal began to emit the escape response spontaneously, which has been termed reversal or therapy (Seligman et al., 1968, 1975; Williams and Maier, 1977).
Despite the frequent replication of the learned helplessness effect (Peterson et al., 1993), two questions have not been well investigated. The first one is related to the fact that most experiments used only two-term contingencies (response and consequence) in the operant test. Considering that the three-term contingency (antecedent–response–consequence) is the traditional unit for operant analysis, it would be desirable to evaluate how the experience with uncontrollable stimuli can interfere with discriminative learning. The few studies that have investigated this question arrive at conflicting results. Consistent with the demonstration that aversive uncontrollable stimuli interfere with subsequent positively reinforced discriminative learning (Rosellini et al., 1982), other studies using similar manipulations either did not produce learned helplessness (Capelari and Hunziker, 2009) or they produced the opposite effect, i.e., subjects previously exposed...
to uncontrollable shocks demonstrated the best discriminative learning (Lee and Maier, 1988).

The second question refers to the almost exclusive use of aversive stimuli in most learned helplessness studies. The few experiments that have manipulated appetitive stimuli have shown contradictory results. For example, among the studies investigating whether uncontrollable aversive stimuli interfere with the learning of a positively reinforced response, some reported difficulty with the learning (Calef et al., 1986; Caspy and Lubow, 1981; Rosellini, 1978; Rosellini and DeCola, 1981; Rosellini et al., 1982), whereas others reported normal learning (Capelari and Hunziker, 2009; Mauk and Pavur, 1979; Rapaport and Maier, 1978). A study using the inverse condition (i.e., the exposure to appetitive uncontrollable stimuli was followed by the escape test) also failed to produce learned helplessness (Capelari and Hunziker, 2005). Others, however, had reported contrary findings (Caspy and Lubow, 1981; Ferrándiz and Vicente, 1997; Sonoda and Hirai, 1992). Accordingly, the question of whether the learned helplessness effect is specific to aversive control remains unanswered.

The goal of the present study was to verify whether subjects that present the typical learned helplessness effect in an escape contingency have equal difficulty learning positively reinforced discrimination. The second goal was to verify whether the “free” exposure to positive reinforcement eliminates the escape learning deficit, similar to that in the forced therapy procedure.

1. Method

1.1. Subjects

Sixteen Wistar rats, approximately 90 days old at the start of the experiment, were housed individually and maintained on a 12 h/12 h light/dark cycle (7am–7pm). Food (dried balanced ration) and water were available in the home cages ad libitum, with the exception of the phases where the rats were water-deprived and maintained on a regimen of 5 min/day with access to water and 10 min at the end of each experimental session.

1.2. Apparatus

Three boxes for the nose poke response, eight boxes for the lever pressing response and one shuttlebox for the jump response were used in the experiment. The boxes with infrared nose poke sensors were 21.5 cm × 21.5 cm × 21.0 cm in length, width, and height, respectively, with frontal Plexiglas walls and aluminum side and back walls. The grid floor was constructed of stainless steel rods 0.3 cm in diameter and spaced 1.3 cm apart. On the center of the right lateral wall and 6.0 cm above the floor was a 3.0 cm diameter aperture that was connected to a 14 cm × 6.0 cm × 9.0 cm (length, width, and height) rectangular box located on the external side of the box. The introduction of an object in this rectangular box (usually the animal’s nose) interrupted an infrared light controlled by a photocell and registered a response (nose poke). Electrical shocks were delivered through the floor by an LVE-133-33 scrambler and shock sources. The boxes were placed in sound and light attenuating chambers made of plywood. The chambers had a glass window that allowed the experimenter to observe the subjects.

The lever press boxes were 27.5 cm × 22.5 cm × 28.0 cm in length, width and height, respectively, with frontal/back walls and ceiling made of Plexiglass and sides made of aluminum. The grid floor was made of stainless steel rods 0.3 cm in diameter and spaced 1.3 cm apart. On the right wall, there was a 5.0 cm × 2.0 cm (length and width) rectangular aluminum lever that was placed 7.0 cm above the floor. A minimum downward force of 45.0 gf (gram-force) activated a microswitch located on the external side of the box, sounded an audible click, and registered a lever press. Reinforcement consisted of 3-s access to 0.05 cm² of water, delivered in an aluminum cup introduced in the water aperture located at the floor level on the center of the right panel.

The shuttlebox was 50 cm × 15.5 cm × 20 cm in length, width and height, respectively, and had non-reflective black Plexiglas sides and back walls and a transparent Plexiglas frontal wall. The box consisted of two compartments of equal size that were separated by an acrylic wall with a 7.5 cm × 6 cm (length and width) rectangular opening 8 cm above the floor, thus allowing the rats to pass from one compartment to the other to escape the shocks. The compartments had independent grid floors that were depressed by the animal’s weight. Once the micro-switch was depressed, the animal’s presence in the compartment was registered. The grid floor was constructed of stainless steel rods 0.3 cm in diameter and spaced 1.3 cm apart. Two cylindrical metal rods similar to those on the floor were located at the base of the opening separating the compartments. The shuttlebox was connected to a BRS Foringer 901 electric shock generator and scrambler, which delivered shocks to the grid floor and metal rods at the base of the opening on the side of the box where the subject was located.

Session control and data recording for the boxes containing levers were operated by two PCs (486 SX and Pentium 133 MHz) with MED-PC software; two 386 PCs with Delphi language software controlled the remaining boxes. Humidity was assessed by a moisture meter during sessions when electrical shocks were used. The humidity in the room was maintained at under 70% using an Arsec 160M3-U dehumidifier.

1.3. Procedure

The experiment, conducted during the light phase, corresponded to three phases: (1) the aversive learned helplessness induction, (2) the discriminative training with positive reinforcement, and (3) the aversive re-test of the learned helplessness.

1.3.1. Phase 1—The learned helplessness induction

Twenty-four rats were randomly divided in triads and exposed to the learned helplessness conventional procedure during two sessions: treatment and test. During the first (treatment) session, the animals were placed in the boxes with nose poke sensors and were exposed to controllable, uncontrollable or no shocks (Groups C, U and N, respectively). The C and U subjects simultaneously received sixty 1.0-mA shocks for a maximum duration of 10 s, presented, on average, every 60 s, (10 to 110 s). The shock for both animals could be turned off by the nose poking response emitted by the subject in Group C. There were no programmed consequences for responses emitted by the subjects of Group U. Therefore, rats from Group U received shocks with the same frequency, intensity and duration as rats from Group C, with the only difference being that the rats in Group U could not control the shock offset. Each shock corresponded to one trial, and the stop time recorded was the escape latency of that trial. If a subject from Group C did not emit the escape response, the shock was interrupted automatically after 10 s, and this latency was registered for that trial. During this session, subjects from Group N remained in a box with a nose poke sensor, but they did not receive shocks.

Twenty-four hours later, all subjects were individually exposed to the test session under an escape contingency in the shuttlebox. After one minute, during which no events were programmed, a series of 60 shocks were administered through the grid floor and steel rods below the aperture between compartments. The 1-mA shocks were presented each 60 s in average (10 to 110 s). Each shock was immediately turned off if the subject jumped from one compartment to the other (escape response). The duration of each shock was registered as the latency to escape in a given trial. If the subject
did not emit the escape response, the shock was turned off after 10 s and that was registered as the latency for that trial.

To reduce the odor resulting from shock exposure, which can present a species-specific eliciting function (Bolles, 1970) and thus interfere with the experiment (Palermo-Neto, 2006), all waste was removed and the experimental boxes were cleaned with water and alcohol after each session.

At the end of this phase, we discarded half of the animals. We retained for the experiment the four triads that demonstrated the most typical behavioral pattern described in the learned helplessness studies. That is, the absence of escape learning in Group U, and escape learning in subjects from Groups C and N. The criteria used to determine escape learning were (1) general decreasing latencies throughout successive trials and (2) final latencies smaller than initial latencies. The criteria used to determine a pattern of absence of escape learning were (1) no systematic decrease in latencies and (2) final latencies not different or greater than initial latencies. In addition to these three groups (N, C and U, within n = 4), we included four naive animals that had remained in their home cages without any treatment during Phase 1 (Group P).

1.3.2. Phase 2—Discriminative training with positive reinforcement

All subjects were submitted to a water deprivation schedule and were then exposed to 12 experimental sessions, 24 h apart, using positive reinforcement to a lever press response. During the first two sessions, the animals were trained to press the lever, using water as the reinforcer. The shaping procedure was conducted manually by a “blind” experimenter who had no access to the subject’s experimental history. After the response was shaped, 100 reinforcers were delivered according to a continuous reinforcement (CRF) schedule.

The discrimination training was conducted during 10 sessions on a multiple schedule of positive reinforcement. The first five sessions consisted of a multiple FR 2 Ext schedule, while the remaining sessions consisted of a multiple FR 4 Ext schedule. Each component was signaled by a different light condition such that a fixed ratio schedule of reinforcement occurred when a light above the lever was on (discriminative stimulus—S^D), whereas no reinforcement (extinction) followed the response when the light was off (delta stimulus—S^A). Sessions were composed of forty 1-min components, distributed equally and randomly between S^D and S^A conditions, with the only caveat being that no more than three equal components would be presented in a row.

At the end of this phase, all subjects were given free access to water in their home cages.

1.3.3. Phase 3—Re-test of the learned helplessness

Twenty-four hours after the last session, subjects from the Groups C, U and N were re-exposed to the escape contingency with the same parameters as described in Phase 1. The only difference was that only 30 shocks were delivered as opposed to 60. Animals from Group P remained in their cages. At the end of this phase, all subjects were again submitted to a water deprivation schedule.

Table 1 reflects the procedure.

<table>
<thead>
<tr>
<th>Groups (n = 4)</th>
<th>Phase 1 (aversive condition)</th>
<th>Phase 2 (positive reinforcement)</th>
<th>Phase 3 (aversive condition)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Treatment (one session)</td>
<td>Test 1 (one session)</td>
<td>Pre-training (two sessions)</td>
</tr>
<tr>
<td>C</td>
<td>60 shocks escape contingency (nose poking)</td>
<td>60 shocks escape contingency (jump)</td>
<td>Shaping CRF (lever press)</td>
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<tr>
<td>U</td>
<td>60 shocks (yoked)</td>
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<tr>
<td>N</td>
<td>No-shock</td>
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1.4. Data analysis

Statistical analysis was conducted with simple analysis of variance (one-way ANOVA) and analysis of variance for repeated measures (two-way ANOVA). When necessary, differences between pairs were analyzed using Tukey tests. Significance level was set at α = 0.05.

In the discriminative training, we analyzed a discriminative index (DI), calculating it using the formula RSD/RSD^0 + RSD^A, where RSD denotes the number of responses emitted in the presence of the S^D and RSD^A denotes the number of responses emitted in the presence of the S^A during the session. A DI of 0.5 indicates that responses were emitted independent of the antecedent stimulus (i.e., non-discrimination); values close to 1.0 indicate greater response frequency in the presence of the S^D; values close to 0.0 indicate greater response frequency in the presence of the S^A. We stipulated DI = 0.8 as a minimum criterion for discrimination.

2. Results

The results obtained during the treatment, Tests 1 and 2, and the discrimination training, are presented in Fig. 1. The line denotes the mean data, and the points represent the individual results. The first graphic, at the top, shows the escape latencies of the nose poking response presented by animals from Group C during the treatment session. A typical pattern of escape learning was observed for these rats: high average nose poking latencies at the beginning of the session, followed by a gradual and systematic decrease throughout exposure to negative reinforcement. Despite the intra-group variability, all animals attained the criterion for escape learning as previously described herein. Latencies were significantly different as functions of successive trials, confirming that their systematic reduction reflects the learning of the escape response [F(11, 33) = 9.80, p < 0.01]. Thus, it is possible to assert that the subjects controlled the shock duration during Phase 1.

The second line represents the results obtained during the first test session of jump escape learning presented by C, U and N animals. Considering the mean results, we note that the subjects of the different groups initially emitted escape responses of similar latencies (approximately 5 to 7 s). However, throughout the session, latency durations began to differ substantially among the groups. Animals who underwent U condition maintained high escape latencies with a slightly increasing pattern in the second half of the session, whereas animals that underwent the C and N conditions showed a gradual decrease in latencies throughout the trials, with values close to 2 s in the final block. The individual data reflect little intra-group variability for C and N animals, but a high variability for the U Group. One animal did not show the jump response during any of the sessions (latencies of 10 s), while another demonstrated latency reduction during some parts of the session, but in the final blocks of the trials, the latencies increased again. Two animals maintained high latencies throughout all sessions. Thus, it seems that one animal did not experience the negative reinforcement, while the others experienced the shock offset contingent
Fig. 1. The first graphic, at the top, shows the latencies of the nose poking escape response presented by animals from Group C during the treatment session. The second line represents the results obtained during the first test session of jump escape latencies presented by C, U and N animals. The third line shows the mean discrimination index for C, U, N and P Groups under the multiple schedule. At the lower end are represented the results during Test 2 for C, N and U Groups. In all graphs, the line denotes the mean data, and the points represent the individual results.
to their responses. This consequence, however, did not change the response latencies. Statistical analyses show significant differences as a function of the treatment previously administered \([F(2, 9) = 9.812, p < 0.05]\) and of the trials \([F(11, 99) = 5.241, p < 0.01]\), with significant treatment \(\times\) trials interaction \([F(22, 99) = 2.836, p < 0.01]\). Post hoc tests indicate that subjects who underwent the U treatment condition were significantly different from subjects who were exposed to N and C conditions \((p < 0.05)\) and that N and C subjects did not differ from each other.

The third line shows the mean discrimination index (DI) for the four groups in each session under the multiple schedules. All animals showed similar performances as characterized by a gradual and linear increase in the discrimination index throughout the sessions. This pattern is quite similar to the mean and individual data, with practically no intra-group variability. Statistical analyses confirm that differences occurred in terms of successive sessions in each phase \([F(9, 108) = 302.477, p < 0.01]\), with no differences among groups.

The escape latencies obtained during Test 2 are represented at the lower end of Fig. 1. All groups initially presented patterns similar to those shown by the end of Test 1, that is, low initial latencies (approximately 1 to 2 s) for subjects exposed to the C and N conditions, and high latencies (6 s) for those exposed to the U condition. The mean patterns remained almost unchanged throughout the entire session. Individually, we observe little variability among animals in Groups C and N. In the U Group, one animal reached the criteria for escape learning in the re-test and three maintained high escape response latencies. Statistical analysis confirms that differences occurred in terms of previously administered treatments \([F(2, 9) = 6.480, p < 0.018]\), without significant differences throughout trials or group \(\times\) trials interaction. A post hoc test indicates that subjects exposed to the U condition were significantly different from subjects exposed to the N and C conditions \((p < 0.05)\), which did not differ from each other.

Fig. 2 shows, for each subject, the time necessary to achieve the criterion for lever pressing acquisition (top) and the time necessary for animals to receive 100 reinforcers under the CRF contingency after they had achieved the criterion for shaping (bottom). Both results are consistent in that, in general, there was an intra-group high variation, with a range of variation between 10 and 40 min for shaping and 25 to 60 min to receive all 100 reinforcers. However, there are no systematic tendencies among them. The statistical analysis confirms no differences among these groups.

The average number of lever presses per session presented during SD and S\(^D\) by subject from C, U, N and P Groups is depicted in Fig. 3. All groups showed a similar pattern, characterized by a greater number of responses in the presence of the S\(^D\) than in the presence of the S\(^D\) during both phases. However, the average number of responses was systematically greater and lower for subjects of Groups N and U, respectively, than for subjects in Group C. Statistical analysis of the discrimination phases show differences in terms of treatment \([F(7, 24) = 26.052, p < 0.01]\) and
sessions \( [F(9, 216) = 25.488, p < 0.01] \), with session \( \times \) group interaction \( [F(63, 216) = 14.019, p < 0.01] \). A post hoc test reveals that differences occurred between \( S^0 \) and \( S^4 \) in all groups \( (p < 0.01) \); under \( S^4 \), there were differences only between Groups N and U \( (p < 0.05) \); under \( S^0 \) condition, no differences were found.

3. Discussion

The data from the present experiment replicate the finding reported by Maier and Seligman (1976) that the exposure to electric shocks is not sufficient to produce the learned helplessness effect. The difficulty in escape learning occurs as a result of the uncontrollability of previously experienced shocks, a pattern that is not observed if the subject had previously controlled the shocks. Moreover, the previous uncontrollable shocks produced two types of interferences, as reported in the literature (Maier and Seligman, 1976; Overmier and Wielkieicz, 1983; Peterson et al., 1993). These interferences include deficit in initiating the escape response (motivational deficit) and no reduction in systematic latencies after experiencing negative reinforcement (cognitive deficit). Therefore, the experimental conditions established herein were enough to replicate the learned helplessness effect as reported in the literature (Hunziker and Santos, 2007), thus allowing the advances as proposed in this study.

The results of Phases 2 and 3 are original findings. The first relevant result is that the same subjects who showed learning difficulties in a negative reinforcement contingency as a result of a previous experience with uncontrollable shocks (learned helplessness) did not show the equivalent effect when exposed to a positive reinforcement contingency. Lever pressing responses were shaped as easily in the subjects previously exposed to shocks (controllable or uncontrollable) as those not exposed to shocks. Furthermore, the response rates in CRF were similar among all four groups. The second important result is that, introducing the stimulus control, no differences were found between groups in the training with the multiple schedules. Finally, the no therapy effect (for three of four animals) after the learned helplessness rats had experienced many successful R–S relations involving control over water delivery was determined to be relevant.

With respect to the shaping condition, it was unexpected that animals previously exposed to one or two sessions of electric shocks would show no differences regarding the time necessary to reach shaping criterion compared to naïve animals. As previously stated, the learned helplessness effect involves either an initiating response deficit as a no selection by the consequence. Both effects should produce strong interference on the shaping procedure, which depends on the animal activity in the experimental box. Furthermore, one could expect that the history with shocks (controllable or not) could induce the animals to be less active in the experimental situation, thereby decreasing behavioral variation in this circumstance. This reduced level of activity could be predicted as a function of the pairing of electric shocks with the experimental box, which would produce aversive CS and thereby reduce response rates. Given that shaping involves the gradual selection of responses that are progressively closer to the target–response and that behavioral variability is the basic condition for the selection of new responses, a decrease in the general activity and behavioral variability could make shaping more difficult. This analysis could be even more accentuated given that the uncontrollability of the shocks usually produces passivity in the learned helplessness animals (Maier and Seligman, 1976; Seligman and Maier, 1967). However, time for shaping was equivalent among groups. Accordingly, these results suggest that the results for the animals exposed to the different treatment in Phase 1 were not substantially different in frequency or behavioral variability compared with the naïve ones.

Because the experimental box is a continuous and diffuse stimulus (i.e., constantly present during the experimental session), it may establish functions different from those acquired by the CS usually implemented. For example, in conditioned suppression studies, the CS are short in duration (few seconds) and presented occasionally during all sessions (Blackman, 1968; Estes and Skinner, 1941). Thus, it is possible that, in spite of its previous pairing with the shocks, the physical characteristics of the experimental box is paired with positive reinforcement contingent under discrimination training. As indicated by some studies on conditioned suppression, the greater the loss of the reinforcer, the lower the level of suppression (Blackman, 1968). Therefore, the immobility possibly elicited by the aversive CS could be compensated by the reinforcement function exerted by water contingent upon responses requiring motor activity (bar pressing response).

The lever press response learning, as well as the establishment of discriminative control independent of previous treatment, as found herein is not compatible with the interpretation that subjects exposed to uncontrollable shocks learn, in a generalized way, that control over the environment is impossible. The same subjects who did not learn to control the duration of the shocks did learn to control the production of water or when to do so, i.e., to do it in a discriminative way. Therefore, the results observed in the present experiment with positive reinforcement suggest that the
learned effect can be more intense (if not restricted) to aversive conditions, and thus, they are not easily generalized to appetitive contingencies.

Given that the literature shows contradictory results regarding the learned helplessness effect under positive reinforcement contingencies, the present results strengthen the hypotheses that the helplessness effect evidenced in aversive tests is not as strong in appetitive tests. In fact, under the conditions tested herein, the previous learned helplessness induction did not affect the difficulty of new learning under two- or three-term contingencies using positive reinforcement. Therefore, it is suggested that the experimental conditions that produced the learned helplessness effect under the escape contingency did not affect positively reinforced learning, with or without the control of an antecedent stimulus.

The present results are consistent with other studies that did not verify difficulty in appetitive learning contexts as a function of previous experience with uncontrollable aversive stimuli (Capelari and Hunziker, 2009; Chen and Amsel, 1977; Hunziker et al., 2006; Mauk and Pavur, 1979; Rapaport and Maier, 1978). Among these studies, the experiment conducted by Capelari and Hunziker (2009) supports that discrimination learning can occur after uncontrollable shocks, but they did not test if the same subjects would have presented learned helplessness in an escape condition. Therefore, the present work advances in that the same subject that demonstrates learned helplessness in the aversive condition does not reveal this same helplessness in an appetitive condition.

In the present experiment, the only interference by previous experience with uncontrollable shocks was reflected in response rate, which remained below the rate shown by other subjects throughout all discriminative training. Because the reinforcement schedule was ratio-based (FR2 followed by FR4), and session duration was fixed, lower response rates, as a consequence, produced fewer positive reinforcers. As such, though they learned control over positive reinforcement and their behavior came under the control of antecedent stimuli, animals with a history of aversive uncontrollability received fewer reinforcers than the maximum amount they could have received if they had behaved as the other subjects. These data suggest that despite a lack of influence over future the emission of positively reinforced responses or perturbation of control by antecedent stimuli, aversive uncontrollability may interfere with behavior by reducing the optimization of positively reinforced contingencies (Catania, 1998). Thus, while exposure to uncontrollability does not affect learning of the S–R–S relation, it does induces subjects to be less active in a contingency, thereby demanding a higher response frequency compared with what was demanded initially in CRF.

These results strengthen the analysis of Hunziker (1997), which noted that there are no systematic data about the learned helplessness in appetitive contexts. If the specificity of the phenomenon in appetitive contexts is confirmed, it will be necessary to reframe the conceptual and theoretical analysis. Until we have systematic demonstrations that the learned helplessness effect can be produced under appetitive conditions, it may be better to define learned helplessness phenomenon as the “difficulty to learn under negative reinforcement as a function of a previous experience with uncontrollable aversive events”. In fact, considering the generalization process, it can be expected that the probability of occurrence of the learned helplessness effect will increase as the similarity among the stimuli manipulated in training and test phases increases. The question is, however, does generalization occur as a result of physical similarity between manipulated stimuli, or is it related to its nature/function (i.e., aversive/appetitive)? Because most studies on learned helplessness with animals use aversive stimuli – electric shock – these variables are mixed. A recent work manipulating two physically distinct aversive stimuli (electrical shock and hot air blast—HAB) demonstrated learned helplessness using uncontrollable shock in the treatment phase and HAB in the escape test (Maestri, 2008). However, given the fact that this work failed to demonstrate learned helplessness with an inverse arrangement (uncontrollable HAB and shock in the escape test), it suggests that more studies must be conducted to identify other variables, such as the stimulus uncontrollability involved in the production of the learned helplessness effect.

Our data confirm only partly Lee and Maier’s study (1988), in which no difficulty learning, but facilitation of discriminative learning, was demonstrated by animals previously exposed to uncontrollable shocks. According to these authors, subjects submitted to uncontrollable shocks are less sensitive to proactiveceptive stimulation (as in the case of non-signalized escape) but are more sensitive to exteroceptive stimuli, which would explain the facilitated learning in the presence of stimuli with discriminative function. However, it is necessary to consider that our study used positive reinforcement in the discriminative sessions, and Lee and Maier used escape from a water maze. Moreover, it is also possible that the uncontrollability of the previous experience, the variability of the nature of the stimuli used in the experimental phases, or the complexity of the operant contingency may be relevant in producing the learned helplessness effect. If so, it will be necessary to separately investigate several variables that are possibly related to the learned helplessness effect, such as the function and physical features of the stimulus, the effect of uncontrollability over the learning of a two-, three- or more-term contingency, among others.

Re-exposure of subjects to the same test condition (Test 2) showed that a prolonged history with positive reinforcement (10 sessions) did not change the probability of learning the escape response for the majority of subjects in that three out of four subjects who had previously demonstrated a strong learned helplessness maintained high escape response latencies. However, the fact that one animal (among the four) reverted to its deficit for escape learning suggests that, in some conditions (or for some subjects), the experience with positive reinforcement may cancel the learned helplessness. Nonetheless, for most subjects, these data suggest that exposure to positive reinforcement does not work as a reliable therapy to reverse the effects of aversive uncontrollability. Furthermore, if learned helplessness is the result of a learning of the impossibility of control over the environment, this learning, perhaps, does not include all stimuli from the environment in a generalized way, but rather, it includes only a few stimulus classes. The identification of characteristics that define this (these) class(es) must also be the subject of future investigations.

Finally, we argue that the slight effect of learned helplessness induction we observed under the positive reinforcement test – the reduction in response rate under discriminative training – must be further explored. According to Ferster (1973), depressed subjects suffer from the lack of reinforcers, especially positive reinforcers. Despite our U animals having had normal interactions with positive reinforcement contingency with respect to a good discriminative pattern, the smaller frequency of responses emitted by this group suggests a decrement of reinforcers received. This can be interpreted as confirmation of the analogy of learned helplessness as a model of depression as even the subjects were not insensitive to positive reinforcement. This is evidenced by the fact they emitted fewer responses than other subjects, even under a contingency where a smaller response frequency represented a smaller gain in reinforcement. If this low frequency of reinforcement is a characteristic of the depressive repertoire, one can conclude that our data confirm the prediction that animals behave in a similar way to that which is described as human depression. More experimental studies, however, must be conducted to determine the limits of this comparative analysis.
Acknowledgments

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References

Maestri, T.C., 2008. Desamparo Aprendido e Imunização com Diferentes Respostas de Fuga utilizando o Jato de Ar Quente como Estímulo Aversivo (Learned helplessness with different escape responses using the hot air blast as aversive stimulus). In: Dissertação de Mestrado. Instituto de Psicologia. Universidade de São Paulo, São Paulo.