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

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ABSTRACT

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 24 h, 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.

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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

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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 (grams-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 cm^3 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 shock 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