Shuttle avoidance: Rapid acquisition by rats to a pressurized air unconditioned stimulus¹

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Thirty-three adult rats were trained in a shuttlebox using a pressurized air IIS and a 65 decibel buzzer CS. All rats avoided the air blast, and 29 achieved the learning criterion (five avoidance responses in any six trials). Twenty-six of these required 20 or fewer trials to reach criterion. Learning was non-incremental: Ss shifted abruptly from escape responding to avoidance responding. Procedural advantages of air-blast shuttle-avoidance training are noted and applications suggested.

For the past 30 years, electric shock has remained the aversive stimulus of choice in the widely used shuttle avoidance task, perhaps by default rather than demonstrated reliability or efficiency. This paper describes a shuttle-avoidance apparatus for rats that uses pressurized air as the aversive stimulus, and the rapid learning observed in it.

Method

The shuttlebox (Fig. 1) is 2 in. narrower in the center than at the ends to reduce the volume of the box and to minimize non-shuttle-compatible motor activity (Trabasso & Thompson, 1962). In addition, dimensions are close to the physical minimum for rats. The size of windows and doors is a matter of preference; these Plexiglas windows were 11 in. x 4 in. One 65 decibel buzzer CS (Faraday, No. 565) is placed 2 in. above a standard shower head (Sears cat. No. 2075) which is set flush into each end wall. Since the diameter of the passage into the shower nozzle is 1/4 in., a short section of 1/4 in. outside diameter copper tubing may be easily soldered in place. To this is attached ordinary air hose which leads from the "out" line on a 24V solenoid

feeder valve (Foringer & Co., No. 1261). The input of each valve is one branch of a "T" fitting which is connected to the source of the pressurized air.³ This source may be either common air nozzles as found in most laboratories, a small compressor, or a compressed air tank. In any case an air pressure regulator (Ward cat. No. 61C9112) should be placed in the line. When there is a sufficient pressure head to the regulator (45 pounds per square inch) a "working load pressure" (one solenoid valve open, the air flowing) of 30 p.s.i. may be set, and the pressure will not waver.

Thirty-three healthy, experimentally naive Sprague-Dawley rats (26 males, 7 females), ranging in age from 90 to 110 days old were used. Animals accepted as Ss had first passed a screening test in which the CS was presented for 10 sec. without the blast. A rat that escaped the buzzer by moving fully into the other compartment more than twice in five trials was not used. The CS-US interval, set by a thermal time-delay relay, was constant for any subject at 8 sec. or 11 sec. The intertrial interval was 2-1/2 min. for most rats, although several were trained at 1 min. ITI. Strength of US was 30 p.s.i. for all rats. Trials were experimenter terminated when a rat had run sufficiently far into the opposite compartment to cross a sighting line 9 in. from the center of the apparatus. Maximum session length was decreased each day: 15 trials for session one, 11 trials for session two, and 9 trials for session three. Rats were trained to a performance criterion of five avoidances in six trials, or, if no learning took place, through 35 trials, whichever came first.

Results and Discussion

Table 1 presents the performance of 29 rats for the three variables commonly used as indices of avoidance-acquisition rate: trials to criterion, total errors to criterion, and trial of first avoidance. Although all avoided, four rats (12 per cent) did not acquire the response to criterion within 35 trials and are not included in the data.

Pearson correlation coefficients for the three variables are: $r_{tc/te} = 0.970$; $r_{tc/fa} = 0.423$; $r_{te/fa} = 0.531$.

Table 1. Mean and Standard Deviation of Rats (N = 29) on Three Measures of Avoidance Acquisition

Acquisition Measure	M (s. e.)	Standard deviation (s. e.)
Trials to Criterion	8.45 (1.33)	7.19 (1.28)
Total Errors to Criterion	6.21 (0.95)	5.14 (0.91)
Trial of First Avoidance	4.28 (0.44)	2.39 (0.42)

Fig. 1. Air-blast shuttle box for the rat. For clarity, only one of each accessory item is shown, although the two compartments are identical in every detail. The legend is as follows: B, buzzer; D, door; SN, shower nozzle; SV, solenoid valve; "T", the "T" fitting (there is only one of these); W, window.

Twenty-six rats (90 per cent of those that learned) acquired the response within two sessions—20 or fewer trials to criterion.

Nine rats (31 per cent) upon avoiding, immediately achieved criterion: their first conditioned response was followed directly by criterion performance. Six others (21 per cent) learned in nearly the same manner: following a successful avoidance, these failed once before commencing the criterion run.

The criticisms of shuttle-avoidance training have been that animals learn it slowly (Baum, 1965) and too few learn it at all (Bindra, 1961). Shuttle-avoiding to air-blast, however, is not acquired slowly, but four to 30 times faster than electric shock avoidance (Vanderwolf, 1963; Theios, 1963 represent the range of electric shock data). The 12 per cent failure rate compares favorably with the usual 25 per cent to 40 per cent failure rate in shuttle-shock-avoidance (Bindra, 1961). Moreover, acquisition rate is not widely variable, and it can be expected that a large proportion of rats 90 or more days old will learn in one 15-trial session. Learning in the air-blast-shuttle-situation is clearly more rapid and efficient than learning in the standard electric shock avoidance apparatus.

Theios & Dunaway (1964) have compared one-way avoidance with shuttle-avoidance (both motivated by electric shock) and found that shuttle-avoidance is not only learned more slowly than one-way avoidance, but that it is acquired in a qualitatively different way as well: shuttle-avoiding is acquired gradually, incrementally, while one-way avoiding is learned in an all-or-none, non-incremental manner. Air-blast-avoidance acquisition, however, appears to be non-incremental. The above authors utilized a statistic based upon those trials between the first conditioned response and the last failure (escape) prior to criterion to assess the nature of acquisition in the shuttle situation. If these trials are divided into halves and the number of conditioned responses (avoidances) in each half is counted, there will be more avoidances in the second half if learning is incremental, and a t-test will be significant. This technique can be meaningfully applied if there are several trials between the first correct response and the last failure, i.e., if the subject oscillates between correct and incorrect responses. When there are so few trials between the first success and the last failure (no oscillation) that one cannot apply this test, one has *prima facie* evidence for non-incremental learning. Such is the case here: 15 rats (52 per cent) shifted from escape responding to criterion avoidance responding in one, or at the most, two trials (e.g., E E E E

A A A A A or E E E A E A A A A). The other 14 rats, evaluated by Theios and Dunaway's method, show no statistical incremental trend ($t = 0.41$; $p > 0.6$). Thus, rats acquired the avoidance response in an all-or-none manner.

Although frequently reported in avoidance studies, trial of first avoidance is not a good index of acquisition rate in this situation. All rats began avoiding air-blast early, perhaps because the air-blast elicits a high proportion of shuttle-compatible activity (Trabasso & Thompson, 1962).

The extremely high correlation between trials to criterion and total errors to criterion further supports the conclusion that acquisition was non-incremental; the correlation will diminish with oscillation, and, were all subjects to learn non-incrementally, would rise to unity.

Shuttle-avoidance apparatus is now widely used in studying learning, the electrophysiology of learning, and the effects of punishment, brain lesions, electrical stimulation of the brain, drugs, and genetic influences on behavior. It would seem that the air-blast situation offers at least procedural advantages (in terms of simplicity, ease, and efficiency) for all of the above. Moreover, pressurized air is most likely an effective aversive agent for many other species; it has been used successfully with cats (Ray, in press). It is possible, also, that air-blast avoidance will facilitate a more searching analysis of one-trial learning, inter-hemispheric transfer, and the effects of brain extracts upon learning.

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Notes

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2. A completely plastic version of the apparatus is now made by K. T. M. Co., 5346 N. Camac St., Philadelphia, Penna. 19141.
3. Previous use of pressurized air is discussed in Ray (in press).