test-anxious college students to talk to themselves constructively has been demonstrated (Meichenbaum, 1971, 1974, in press; Wine, 1971). The theory of operant elements and the attendant theory of response integration (Klinger, 1971) may help to account for and extend these results. Third, the view taken here suggests an approach to the general study of self-regulation.

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NOTE

1. Ideally, the conditions would, of course, have been counterbalanced. However, the data of Experiment 1 are a portion of an unfinished counterbalanced design originally begun for another purpose, a content analysis of segmental structure, described elsewhere (Klinger, 1971). It became apparent much later that the data could be used to test the newly formulated hypotheses concerning operant elements. Experiment 2 was performed subsequently to inquire whether the earlier results could be attributed to order. Since the effects were replicated in essentials, examination of still other orders seemed highly unlikely to discover anything further.

(Received for publication April 9, 1974.)

Bulletin of the Psychonomic Society
1974, Vol. 4 (1), 46-48

Operant performance in inbred mice*

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The procedures described in this report are standard operant procedures, which have been used successfully to condition mice to barpress for a food reward on a variety of schedules of reinforcement. The schedules of reinforcement include continuous reinforcement, nine fixed ratio values, and six fixed interval values. Mice of five genotypes have been exposed to some or all of these schedules. Performance was typical of that observed in other organisms, and satiation was not a problem in sessions lasting from 2 to 3½ h. This experiment clearly demonstrated that barpress performance can be obtained with inbred mice as readily as with other organisms.

Recent advances in behavior-genetic research using genetically controlled populations of mice have resulted in a considerable increase in the sophistication of behavior-genetic techniques. As a consequence, inbred mice and their derivatives are being used with increased frequency in other biological disciplines when behavioral questions arise. Superior genetically controlled mice

*This research was supported by an allocation from General Research Support Grant RR 05545 from the Division of Research Resources to the Jackson Laboratory and by Institutional Funds of the Jackson Laboratory. The Jackson Laboratory is fully accredited by the American Association for Accreditation of Laboratory Animal Care.

used in combination with powerful behavioral techniques can provide highly useful analyatical tools. Freund and Walker (1972) make this point well in a recent paper describing the use of mice in an operant conditioning situation and the possible applications of this procedure to chemical toxicity tests.

While it is true that the use of inbred mice in operant conditioning situations could contribute to research in areas such as psychopharmacology (Freund & Walker, 1972), reproduction, nutrition (Sprott, 1972), and physiology (Sidman, Ray, Sidman, & Klinger, 1966), the technique has apparently not been used with any frequency for two reasons. First, operant techniques typically require instrumentation which appears complicated. Second, there is widespread, but almost undocumented belief among behavioral (and perhaps other) scientists that laboratory mice cannot be conditioned successfully in an operant situation. This misconception appears to be supported by two facts: (1) there are, to our knowledge, only seven studies reported in the literature which use mice and operant techniques. Of these studies, only four use a barpress operant (Freund & Walker, 1972; Anliker & Mayer, 1956; Goodrick, 1967; Howard, 1973), which is the standard operant response when rats are used as Ss. In the other three reported studies, a licking operant was employed (Sprott, 1972; Sidman, Ray, Sidman, & Klinger, 1966; Sprott, Clark, & Wimer, 1970). (2) No studies are available in the literature which report successful use of standard deprivation procedures, barpress operant, and laboratory mice in combination. In fact, the Freund and Walker (1972) report suggests that standard techniques must be modified considerably in order to successfully employ mice as Ss.

Since we have been successfully using inbred, hybrid, and mutant mice in a licking operant situation for over 4 years and in a standard barpress operant situation for over 2 years with very little modification of standard procedures, we are convinced that the belief in the lack of suitability of mice as operant Ss is in fact groundless. The purpose of this report is to describe our procedures and results in order to demonstrate that mice are suitable operant Ss, and therefore, that the powerful combination of genetically defined S populations and operant conditioning techniques is available for use for many problems. Since some of our studies with the licking operant have been described elsewhere (Sprott, 1972), we will confine this report to a description of our barpress procedures and results.

MATERIALS AND METHODS

Subjects

Twelve mice of five genotypes have served as Ss for periods up to 7 months each. The five genotypes include two inbred strain, C57BL/6J and DBA/2J; the F_1 hybrid between these two strains, B6D2F_1; obese mutant mice on a C57BL/6J background, C57BL/6J ob/ob; and their normal littermates, C57BL/6J +/?. All mice were obtained from the Production Department of the Jackson Laboratory at 6 weeks of age and were introduced to the operant situation at 8 weeks of age. The mice were housed individually in clear plastic cages in a research colony room which was maintained at 72° ± 2°F with a 12 h on, 12 h off light cycle.

Apparatus

Two identical operant conditioning chambers were constructed using 1/8-in. clear Plexiglas. The basic chamber dimensions were 3¾ x 3 x 4¾ in. deep. Each chamber was provided with a grid floor of 3/32-in. stainless steel rods. A mouse lever (Lehigh Valley Model No. 1535) was mounted on one wall of the chamber 1½ in. above the grid floor. A Plexiglas pellet tray was mounted on the same wall to the left of the lever. Solid food pellets (Noyes Formula M) were delivered to the tray by means of a pellet dispenser (Gerbrands Model D-1). For most of the period covered by this report, 45-mg pellets were used. However, we have recently converted to the use of 20-mg pellets. Schedules of reinforcement were programmed using standard relay circuitry. Responses and reinforcement were programmed using standard relay circuitry. Responses and reinforcements were recorded on cumulative recorders (Gerbrands-Harvard Model C-3). Water was available ad lib during experimental sessions. Both chambers were housed in a sound attenuated box equipped with an exhaust fan to provide air circulation. The chambers were a modification of the chamber built for licking operant studies reported elsewhere (Sprott, Clark, & Wimer, 1970).

Procedure

Each mouse was weighed daily for 5 days prior to testing to determine a mean ad lib weight. At the end of this 5-day period, the mice were given 6 g of mouse food (Old Guilford-911R, Emory Morse) to carry them over the next 3 days. This procedure usually results in a reduction to approximately 80% of ad lib weight. Adjustments in food available are then made to achieve the 80% level. The mice are then maintained at this level with the pellets obtained in experimental sessions plus a supplement of 0 to 1 g of mouse food each day. Mice were tested 5 days/week and given 6 g of food on Fridays to carry them over weekends.

We have so far successfully conditioned mice using 16 schedule of reinforcement values. These values include: continuous reinforcement (CRF); fixed ratio (FR) schedules with ratios of responses to reinforcements of 5, 10, 15, 25, 40, 60, 100, 120, and 200; fixed intervals (FI) with the interval values in seconds of 21, 45, 60, 90, 120, and 150. All FR schedules used 45-mg pellet reinforcements, while FI schedules have been used with both the 45-mg and the 20-mg pellets. At least one mouse of each genotype has been exposed to a schedule with a 20-mg reinforcement, and at least one mouse of each genotype has been exposed to FR and FI schedules. The range of schedules to which all genotypes have been exposed is: FR 5 to FR 40, and FI 100 to FI 150 with 20-mg pellets. Nonmutant mice have been exposed to all FI schedules, and C57BL/6J mice have also been exposed to all FR schedules as well. Test sessions lasted from 2.0 to 3.5 h depending upon the schedule.

RESULTS

The standard Lehigh Valley lever was adjusted to require a force of 10 g for depression. At this value, all of our mice are able to depress the lever.

Figure 1 shows six selected cumulative recordings,

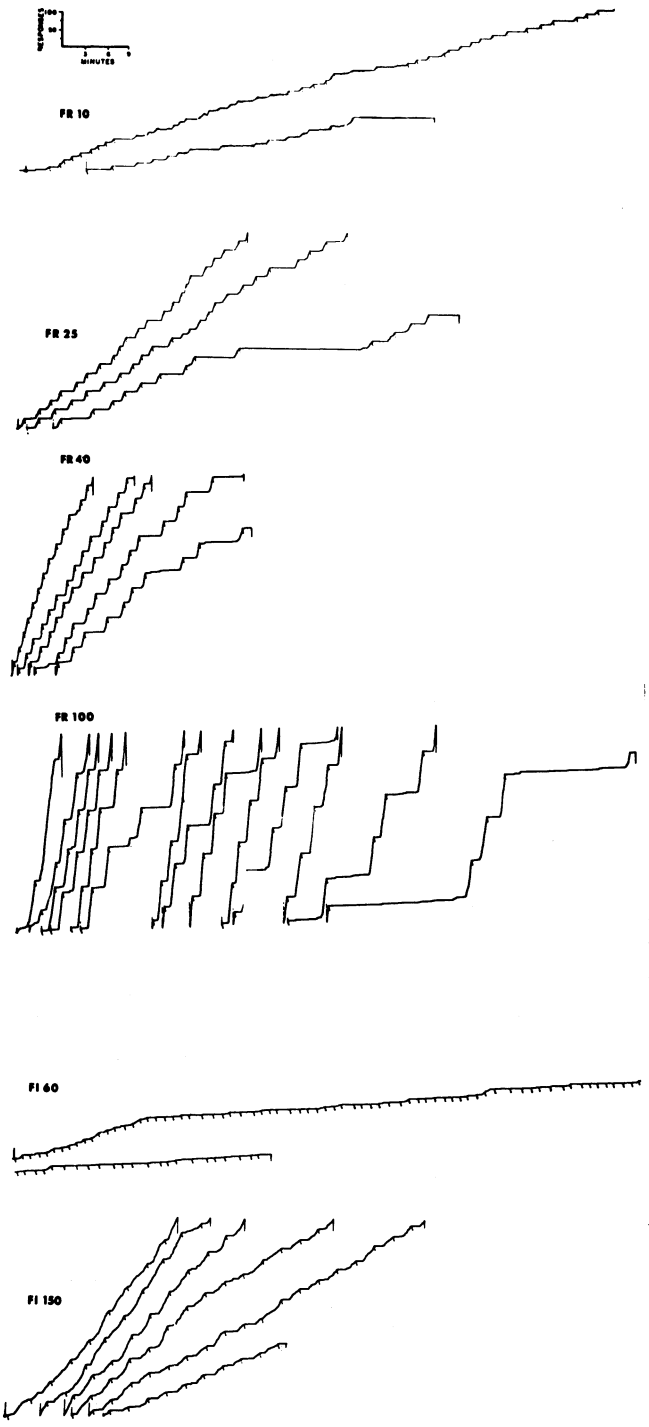

Fig. 1. Representative cumulative records of the performance of laboratory mice barpressing for a food reward. The FR 10, FR 40, and FR 100 records were produced by C57BL/6J mice. The FR 25 record was produced by an obese mutant (ob/ob) mouse. The FI 60 record was produced by a DBA/2J mouse, and the FI 150 record was produced by a C57BL/6J x DBA/2JF$_1$ hybrid mouse. The scale in the upper-left corner shows the distance of pen travel for 100 responses (upward) and with time (left to right). The marks produced by a momentary downward displacement of the pen mark the occurrence of reinforcement.

four from FR schedules and two from FI schedules. These records were selected because they are representative of the performance observed with our procedures. They are neither the best (highest rate of response) nor the worst (low rate or unstable), but fairly represent typical performance. Each record shows a complete session lasting from 2 to 3½ h. It should be noted that satiation effects (low rate or long pauses) are only observed late in these sessions and, then usually, on FR schedules with a high-reinforcement density (FR 10 and FR 25). These performances are comparable to those observed with other organisms (Ferster & Skinner, 1957) and are certainly adequate to serve as baselines for behavioral tests requiring up to 2 h (e.g., time course of drug action).

DISCUSSION

Previous reports have suggested that mice could be conditioned in a barpress operant situation, but the general dearth of such studies plus a more recent report of methodological difficulties (Freund & Walker, 1972) have supported the general belief that mouse operant conditioning is extremely difficult. . Since there is also a general conviction that the use of genetically controlled mice in operant situations could constitute a powerful analytical tool, the fact that typical barpress operant results can be obtained with mouse Ss, using standard techniques should be of considerable interest. We cannot account for the difficulties reported by Freund and Walker but can guess at possible problems. Our chamber is much smaller than theirs and keeps the S in closer proximity to the bar and reduces the amount of "irrelevant" activity observed. Also, the lever must be adjusted so that no more than 10 g of force are required for depression. It is also possible that the height of the lever is critical, although this seems unlikely. Finally, we have no way of accounting for the satiation problems in Freund and Walker report since we have not observed them with either 45- or 20-mg pellets. In conclusion, it seems to us that mouse-operant conditioning is no more difficult than that with any other organism, and that the procedure can be used in any experiments which require or can profit from a high degree of behavioral control of genetically defined mammalian Ss.

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(Received for publication April 11, 1974.)