consummatory patterns. Jensen (1963) concluded, however, that barpressing may have an intrinsic attractiveness for rats. Results of the post hoc analysis seem to support this notion, as the mean amount consumed per animal was significantly higher during both training and choice days, than for free days. This would indicate that the reward via barpressing was stronger than when it was freely obtainable. Since this trend occurred in all groups (nonnutritive as well as nutritive), it would appear that it is this intrinsic attraction which Jensen described and not the consummatory patterns of Carder which best explained the barpress vs freeloading phenomenon. It would seem then, that while a reinforcer with some food value is needed for food deprived animals, this alone does not explain what the intrinsic attraction is that compelled the animals to "work" for the greater portion of the total amount consumed when the reinforcer was freely available.

The results also indicate that the performance in the choice situation is contingent on the reinforcer, and not on the state of deprivation, as water deprived animals consumed more either by freeloading or via barpressing depending upon which reinforcer was used. In all situations but one, however, the animals preferred to barpress rather than to freeload.

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Microanalysis of fixed-ratio performance in the rat: Behavioral tolerance to morphine*

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Rat performance under a fixed-ratio schedule of food reinforcement was analyzed in terms of distributions of intervals between successive responses (IRTs). A 20-mg/kg IP injection of morphine increased the proportion of longer IRTs without affecting the modal IRT, and increased mean IRT at all positions in the ratio. Fixed-ratio performance returned to baseline during repeated administration of the drug.

Weiss and Gott (1972) analyzed the fixed-ratio performance of pigeons in fine detail by recording and examining in order the intervals between each of the 30 keypecks required for grain presentation (FR 30 schedule of food reinforcement). Amphetamine, imipramine, and pentobarbital were administered, and the authors concluded that these drugs acted mainly on the cohesiveness of the fixed-ratio pattern of keypecking. Subsidiary effects concerned the distributions of interresponse times (IRTs). At the doses used, amphetamine and imipramine, as well as breaking up the coherence of the performance, also increased the frequency of IRTs having twice the duration of the modal IRT. Pentobarbitol promoted coherence of FR performance and increased the frequency of IRTs having one-half the duration of the modal IRT.

The present experiment reports a similar analysis carried out during observations of the development of tolerance of the fixed-ratio performance of rats to repeated administration of a moderately large dose of morphine. Behavioral tolerance to morphine has not been demonstrated in the rat. Such tolerance has been

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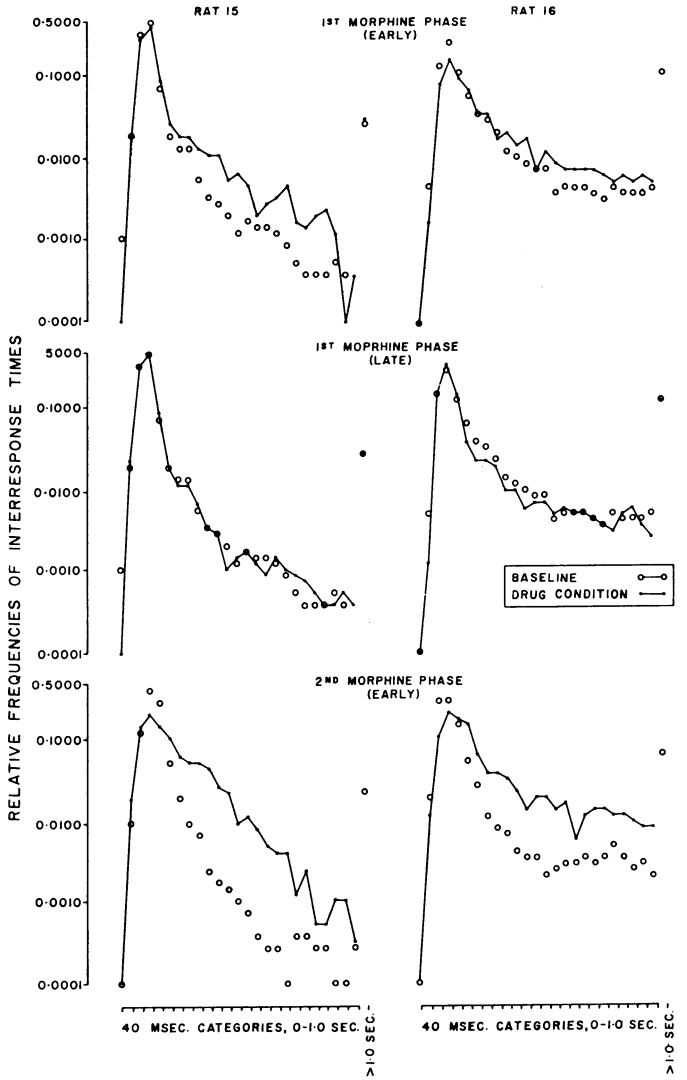

Fig. 1. Interval histograms showing distribution of IRTs in 40-msec categories for each of two rats under three drug conditions, together with respective baseline performances. Each graph is based on data aggregated from three sessions. Note logarithmic ordinate: 0.0001 has been added to each value to avoid infinite extension of scale.

shown in pigeons by Heifetz and McMillan (1971), but tolerance was complete only with respect to performance under a fixed-interval schedule of grain presentation; FR performance remained depressed, even after 25 days of morphine administration.

METHOD

Subjects and Apparatus

Data are reported from two male Wistar albino rats. They were aged about 60 days and weighed about 200 g when they arrived from Woodlyn Farms. Subsequently, their weights were allowed to rise to 300 g where they were maintained by controlled feeding after daily experimentation.

Two standard Grason-Stadler two-bar rat chambers (Model E3125B) were used, each with the right-hand bar removed, and each equipped with a food dispenser that provided one 45-mg Noyes pellet for every 40th depression of the remaining response bar. Scheduling, recording, and data analysis were conducted on-line by a Hewlett-Packard 2100 computer located in an adjoining room.

Procedure

Both rats were given identical treatments, which, once stable FR 40 performance had been established, comprised a 15-day phase of morphine administration followed 50 days later by a further 6 days of morphine administration. Each phase was preceded by at least 3 days during which saline was administered. On each experimental day the rats worked for 10 min on the FR 40 schedule (presession). Then they were withdrawn from the experimental chamber for 5 min, during which time morphine (20 mg/kg) or an equivalent volume of saline was injected intraperitoneally. Subsequently they were exposed to the FR 40 schedule until 52 pellets had been gained, or until 45 min had elapsed, whichever happened first.

RESULTS

The main effect of morphine on behavior was to increase the proportion of longer IRTs, although the location of the modal IRT was barely affected. This is clear from the top and bottom pairs of panels of Fig. 1, which compare performance during the second, third,

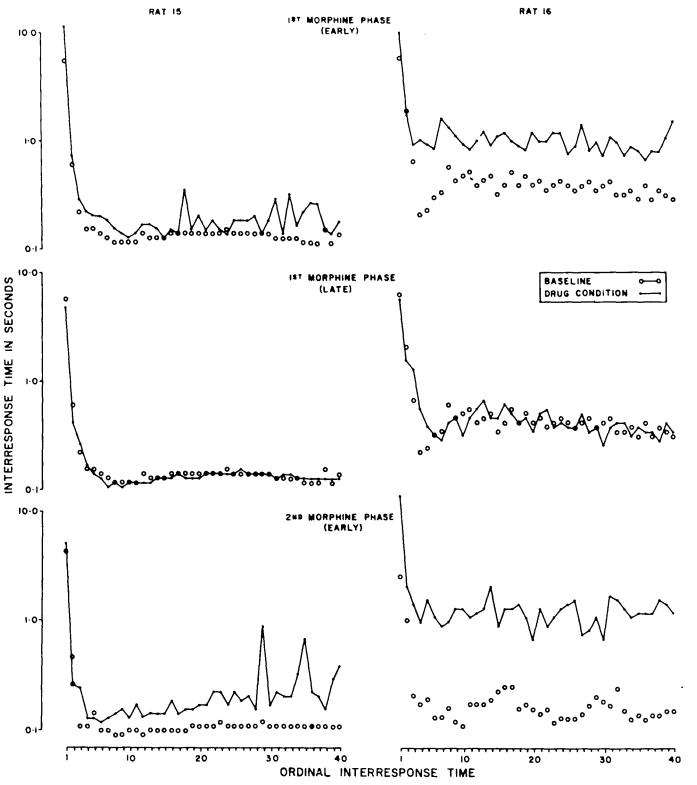

Fig. 2. The data used to construct Fig. 1 arranged to show ordinal IRT duration. Note logarithmic ordinate.

and fourth sessions of each morphine phase with performance during the three saline sessions that preceded the respective phase (responding was severely depressed during the first session of each phase).

IRTs were recorded only during main sessions, and then only after two pellets had been delivered. The corresponding panels of Fig. 2 show that the IRT increases were distributed evenly throughout the ratio. There was no evidence of subsidiary peaks in the IRT distribution under saline or morphine conditions.

The central pair of panels of each figure shows performance during the final three sessions of the first morphine phase, with the prephase saline performance for comparison. It is clear that morphine was no longer affecting FR performance.

DISCUSSION

Baseline IRT distributions resembled those reported for the pigeon by Weiss and Gott (1972), except that consistent subsidiary peaks were not observed.

This difference almost certainly reflects the difference in topographical relations between the pigeon and its response key on the one hand, and the rat and its response bar on the other.

The initial lengthening of IRTs by morphine was similar to the rate-depressant effects of this drug on pigeon fixed-ratio performance reported by Heifetz and McMillan (1971), and also to the same effect reported for the rat by Thompson, Trombley, Luke, and Lott (1970). It also resembles to some extent the IRT lengthening caused by the larger doses of both amphetamine and imipramine in the study by Weiss and Gott (1972). However, in their data, a substantial proportion of the IRT lengthening was confined to elevation of the appropriate subsidiary peak. Their results leave the impression that the cohesiveness of the FR pattern may have been unaffected by these two drugs, except to the extent that the pigeons emitted more tentative or misdirected pecks. The present data, by contrast, show a more uniform increase in the proportion of longer IRTs, providing stronger evidence for a drug-induced breakdown in the cohesiveness of the FR pattern. It is clear that the components of ratio runs can be separated by appropriate procedures, as may the components of simple heterogeneous chains (Gilbert, 1970).

The present data demonstrate complete tolerance of rat FR performance to a repeated, moderately large dose of morphine, but offer little clue as to the mechanism of tolerance development. Tolerance did not persist once morphine was withdrawn; the effects of morphine at the beginning of the second phase were stronger, if anything, than the effects at the beginning of the first phase.

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