

**DEVELOPMENT OF BEHAVIORAL COMPENSATION  
TO THE EFFECTS OF SCOPOLAMINE DURING  
FIXED-INTERVAL REINFORCEMENT<sup>1</sup>**

NICOLAS H. CHARNEY AND G. S. REYNOLDS

THE UNIVERSITY OF CHICAGO

Rats were injected with scopolamine before every daily session of water reinforcement on a fixed-interval (FI) schedule. Initially the drug decreased the rate of responding. Control injections of scopolamine following each session did not. Over 119 sessions, the typical FI performance developed more slowly in the animals drugged before the sessions. Their rates of responding increased from session to session, to a level slightly greater than that of the animals drugged after the sessions. Their rates did not increase. The effects of injections before the session were not duplicated by increasing the deprivation of animals drugged after the session.

The first few injections of scopolamine on a rat's well-developed, stable performance on an FI schedule of reinforcement decrease greatly the over-all rate of responding and reduce the typical, cumulative curve of increasing slope to an irregular straight line showing no consistent discrimination of time within the fixed interval (*e.g.*, Herrnstein, 1958; Boren and Navarro, 1959). The present data show that chronically drugged animals can develop a stable temporal discrimination within the fixed interval, and with a high over-all rate of responding.

### METHOD

#### *Subjects*

Four, male, hooded rats, 150 days old were deprived of water 23.5 hr before each session, and drank 10 cc of water after each session. The weight of the animals began at an average of 400 g, but slowly decreased over the course of the experiment. All injections were given intramuscularly into the left rear leg.

#### *Apparatus*

The experimental chamber measured 12 by 12 by 18 in. long and contained a lever on one

wall 2 in. above the floor. Depression of the lever operated automatic programming equipment which intermittently injected a small drop of water into a tray near the lever. Termination of each session was indicated by turning off the overhead illumination in the chamber. White noise was used to mask extraneous noise.

#### *Procedure*

Subjects were trained to press the bar with water reinforcement. They were then maintained on a VI schedule of reinforcement with an average interval of 1 min. After several sessions, they were reinforced daily on an FI 1 schedule. This schedule reinforces the first response that occurs 1 min after the last reinforced response. The sessions ended after 24 reinforcements. Responses were recorded cumulatively, and on mechanical counters. One counter gave the total number of responses for the session. The distribution of the responses during the 1-min intervals was recorded by four other counters which separately cumulated the responses that occurred in successive 15-sec segments of each of the 24 1-min intervals.

After one session of FI reinforcement, rats N1 and N2 were injected with 0.4 cc of saline 10 min before each session and 0.4 cc of a scopolamine hydrobromide solution (approximately .6 mg/kg) immediately after each session. Rats N4 and N6 were injected with 0.4 cc of the scopolamine solution 10 min before each session and with 0.4 cc saline after the session. This dose was later changed for one

<sup>1</sup>Research supported by grant GB-316 from the National Science Foundation and by grant MH 08076-01 from the National Institutes of Health, both to the University of Chicago. Reprints may be obtained from G. S. Reynolds, Department of Psychology, University of Chicago, 5728 South Ellis Avenue, Chicago, Illinois 60637.

of the rats, as noted below. Thus, N1 and N2 were always drugged after the session, while N4 and N6 were always drugged before the session.

All subjects received the same amount of scopolamine and of saline during a 24-hr period. Thus, any differences in the performances would seem attributable to when the animal was drugged rather than to any long-term effects of the drug, *e.g.*, on the power of the reinforcer or on the ability of the animals to emit the reinforced response.

The injection and training procedure continued daily for 119 experimental sessions. In sessions 98 and 99, the duration of water deprivation was increased from 24 to 48 and from 24 to 72 hr, respectively.

### RESULTS

The contingencies of reinforcement set up by an FI schedule of reinforcement typically

generate a response pattern distinguished by infrequent responding just after reinforcement and a usually gradual increase in responding as the time of the next reinforced response approaches. Figure 1 shows that this typical performance develops in the animals drugged after the sessions, and that it develops at a much slower rate in animals drugged before the sessions. The number of responses, cumulated for 24 1-min intervals, that occurred in each successive 15-sec segment of the intervals is plotted as a function of the class-interval of time within the interval, for all four rats in sessions 1, 13, 50, and 118. From top to bottom, the graphs in each column of the figure trace the development of an animal's performance. By session 13, both subjects (N1 and N2) drugged after the session were approaching a typical performance (*cf.* session 118), but the animals (N4 and N6) drugged before the session were not. By session 50, the drugged animals had improved, but were not

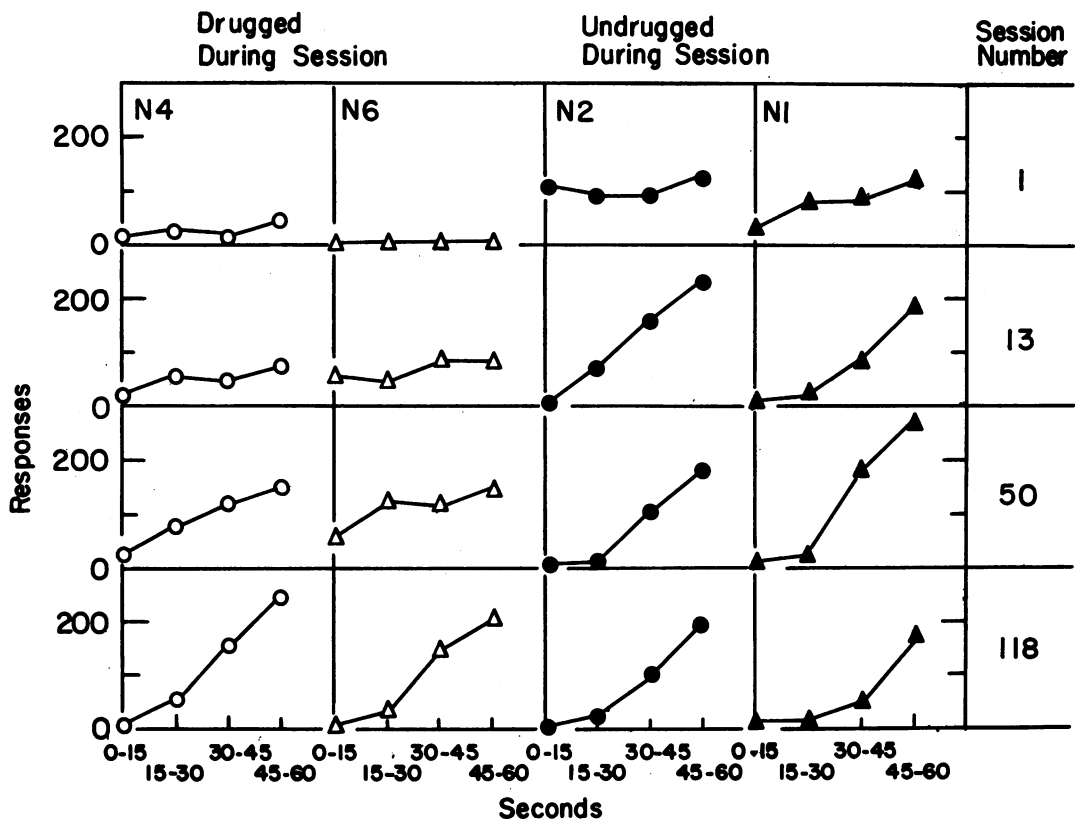


Fig. 1. The number of responses, cumulated for 24 1-min fixed intervals, that occurred in each successive 15-sec segment of each of the intervals as a function of the class-interval of time within the interval. Sessions are numbered at the right both for animals drugged before the session (N4 and N6) and for animals drugged after the session (N2 and N1).

up to the level of the undrugged animals in session 13.

Figure 2 shows the distribution of responses throughout the 1-min intervals. The percentages were obtained by dividing the number of responses cumulated in each 15-sec segment of the 24 intervals by the total number of responses. Up to session 53, data from every fourth session appear in the figure. After session 53, data from 64 sessions have been omitted. The slower development of the performance of the animals drugged before the session is seen in the slower decline of responding in the first 15-sec segment of the interval (filled circles) and the slower increase in responding during the last 15-sec segment of the interval (inverted triangles), when compared to the performances of the animals drugged after the session. By session 119, the animals drugged before the session emitted about 50% of their responses in the last 15-sec segment of the interval.

Chronic injections of scopolamine also affected the total output of responses. Figure 3 shows the total number of responses in every

fourth session. Again, 64 sessions are omitted following session 53. Session 0 was the first in which the FI schedule was in effect, and the only session of that schedule with no injections. Injecting the drug before the session initially depressed responding below the level prevailing in session 0 (left col.). Injecting the drug after the session did not (right col.). (From session 5 on, only 0.2 cc scopolamine were injected into N6, because of the extreme depression of its responding by 0.4 cc and because the behavior of N6 with 0.2 cc resembled closely the behavior of N4 with 0.4 cc.)

After the initial depression of responding, there was a gradual increase in the number of responses emitted by the animals drugged before the session. By session 119, both were emitting more responses than the two animals drugged after the session. The total responses of the two drugged after the session fluctuated, but ended in session 119 at about the same or at a lower level than in session 0.

Increased water deprivation from 24 to 48 and from 24 to 72 hr tended to increase the rate of responding of all animals, but the effect

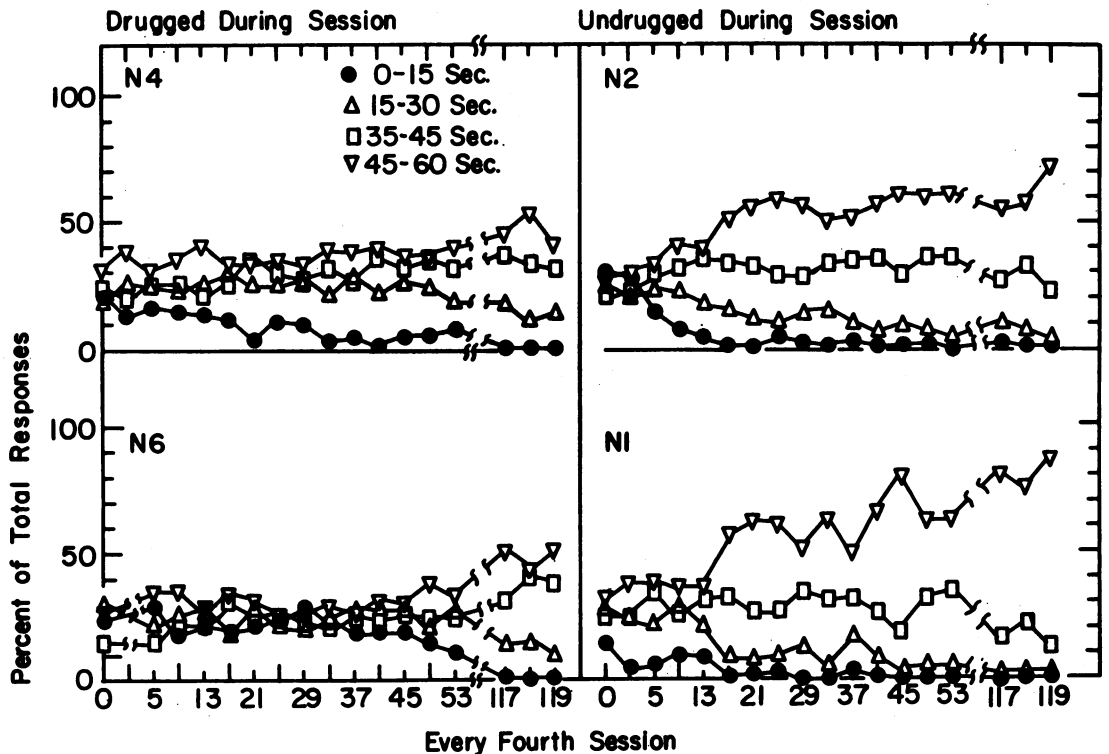


Fig. 2. Distribution of responses throughout the 1-min intervals. The percentages were obtained by dividing the number of responses cumulated in each 15-sec segment of the 24 intervals by the total number of responses. Data from every fourth session are included up to session 53 after which data from 64 sessions have been omitted.

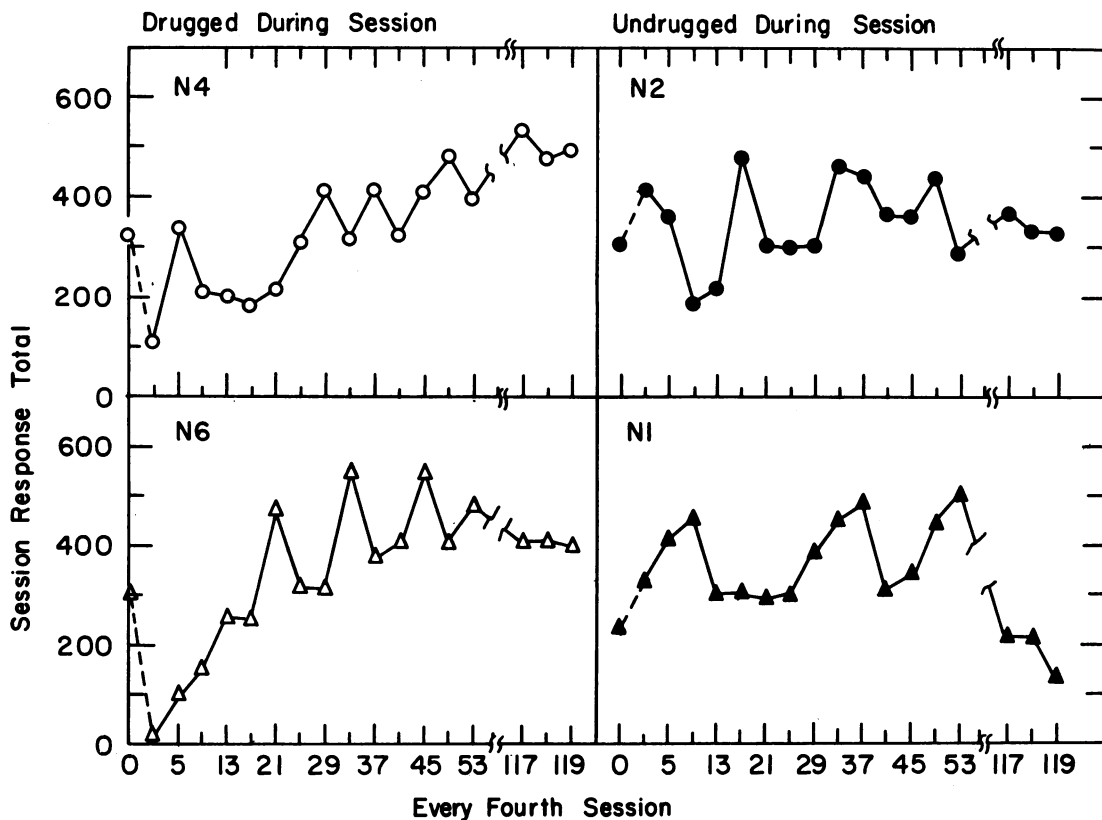


Fig. 3. The total number of responses in every fourth session of FI reinforcement. After session 53, data from 64 sessions are omitted.

was neither reliable nor significant. The distribution of the percentage of responses within the interval remained the same (cf. Weiss and Moore, 1956). It seems unlikely, therefore, that all the present effects result from an alteration by scopolamine of the animal's thirst.

DISCUSSION

A temporal discrimination developed when scopolamine was administered before daily sessions of FI reinforcement. The discrimination, however, did not reach the level that developed in control animals drugged after the sessions (23.5 hr before the next session). In this sense, behavioral compensation to the effects of scopolamine is not complete.

The total rate of responding also shows compensation. The rate maintained in animals drugged before the sessions continued to

increase to a level higher than the original rate of responding of these animals as well as slightly higher than the original and final rates of animals drugged only after the sessions. This long-term, chronic effect of scopolamine may thus be in a direction opposite to the original, acute effect of depressed responding.

REFERENCES

Boren, J. J. and Navarro, A. P. The action of atropine, benactyzine, and scopolamine upon fixed-interval and fixed-ratio behavior. *J. exp. Anal. Behav.*, 1959, 2, 107-115.  
 Herrnstein, R. J. Effects of scopolamine on a multiple schedule. *J. exp. Anal. Behav.*, 1958, 1, 351-358.  
 Weiss, B. and Moore, E. W. Drive level as a factor in distribution of responses in fixed-interval reinforcement. *J. exp. Psychol.*, 1956, 52, 82-84.

Received November 16, 1964