

*THE ROLE OF VERBAL BEHAVIOR IN
HUMAN LEARNING: INFANT PERFORMANCE
ON FIXED-INTERVAL SCHEDULES*

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The performances of two infants less than one year old were investigated on fixed-interval schedules. When the infants touched a cylinder either music or food was presented according to fixed-interval schedules ranging in value from 10 to 50 seconds. With respect to two principal criteria, namely, pattern of responding and sensitivity to the schedule parameter, the subjects' behavior closely resembled that of animals but differed markedly from that of older children and adults. Negatively accelerated responding in the course of the fixed interval in the early sessions gave way to a scalloped pattern, consisting of a pause after reinforcement followed by an accelerated response rate. This scalloped pattern was the final form of responding on all schedule values. Analysis of data after performance had stabilized showed that postreinforcement pause was a negatively accelerated increasing function, and running rate (calculated after excluding the postreinforcement pause) was a declining function, of schedule value. On each schedule, the durations of mean successive interresponse times declined in the course of the fixed interval and were directly related to schedule value. The results supported Lowe's (1979) suggestion that verbal behavior may be responsible for major differences in the schedule performance of older humans and animals.

Key words: verbal behavior, learning, fixed-interval, scalloping, postreinforcement pause, interresponse times, response rate, cylinder-touch responses, human infants

How human operant behavior is determined and whether it is subject to the same controlling variables as animal behavior is an issue that has attracted considerable attention and some controversy in recent years (Bradshaw, Ruddle, & Szabadi, 1981; Brewer, 1974; Catania, 1981; Lowe, 1979, in press; Shimoff, Catania, & Matthews, 1981). The problem is well exemplified by performance on schedules of reinforcement. In the case of animals, schedule effects are orderly and generally replicable within and across species, and the characteristic patterns of behavior generated by the basic schedules have become widely known (Ferster & Skinner, 1957; Morse, 1966; Zeiler, 1977; but see also Lowe & Harzem, 1977). Human schedule performance, on the other hand,

frequently bears little resemblance to that of any other animal species. This is evident not only in response patterning but also in sensitivity to schedule parameters. The orderly and systematic relations between various response measures and schedule parameters that are observed in animal studies are very often absent in human schedule performance, and human behavior shows a rigidity, i.e., a persistence of particular behavior patterns in the face of changed schedule conditions, which is not present in animal behavior (Leander, Lippman, & Meyer, 1968; Long, Hammack, May, & Campbell, 1958; Weiner, 1965, 1969; for a review of the literature, see Lowe, 1979).

When human subjects aged four and upwards perform on conventional fixed-interval (FI) schedules, for example, the resulting pattern of behavior is not the classic FI "scallop" but usually takes one of two forms, which are shown in Figure 1: (A) a continuous and high rate of responding between reinforcers, or (B) a very low response rate consisting of just one or two responses at the end of the interreinforcement interval. Both these patterns of behavior have frequently been observed in different subjects in the same study (cf. DeCasper &

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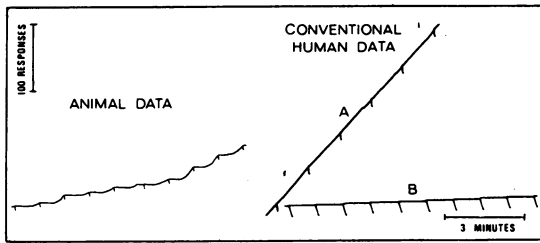


Fig. 1. Cumulative records of typical animal and human performance on fixed-interval schedules showing the stable performance of a rat and of two human subjects on an FI 60-sec schedule. The record labeled 'A' exemplifies the high-rate pattern and that labeled 'B' shows low-rate performance. The two human subjects pressed a panel for points that were later exchanged for money (from Lowe, 1979; reproduced by permission of John Wiley and Sons, Ltd.).

Zeiler, 1972; Leander et al., 1968; Lippman & Meyer, 1967; Long et al., 1958; Lowe, 1979; Weiner, 1969).

The sensitivity of FI performance in relation to the duration of the schedule value has been extensively studied with animals, and measures such as postreinforcement pause and response rate have been shown to be related in an orderly fashion to that temporal parameter (Hanson & Killeen, 1981; Lowe, Harzem, & Spencer, 1979; Lowe & Wearden, 1981; Zeiler, 1977). Comparable functions have not been obtained from humans. There is a simple, almost one-to-one relationship between the occurrence of responses and reinforcers in the behavior of human subjects who produce the low-rate pattern; the response rate of the high-rate subjects is unaffected by changes in the FI schedule over a wide range of schedule values and many experimental sessions (Leander et al., 1968; Weiner, 1969).

Patterning on fixed-ratio (FR) schedules is also very different for animals and humans. Although postreinforcement pauses occur in animal FR performance, with pause durations systematically related to the value of the fixed ratio, a number of studies have failed to obtain postreinforcement pauses with humans on FR schedules; responding frequently consists of a high steady rate that is unrelated to the schedule parameter (Holland, 1958; Weiner, 1964a, 1965, 1970). If human subjects first perform on FR schedules, constant high rates of responding are generated that persist unaltered for many sessions when the schedule is changed to FI. Alternatively, if the initial schedule is one that generates a low response rate, e.g., a differ-

ential-reinforcement-of-low-rate (DRL) schedule, then subsequent performance on FI schedules will be of the low-rate type (Weiner, 1964b, 1969). Such marked and persistent effects of reinforcement history are not found in animal performance on these schedules.

Two recent attempts to account for differences in the operant behavior of animals and humans have appealed to verbal behavior as a critical variable. One analysis (Catania, 1981; Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff et al., 1981) stresses the importance of instructions provided by the experimenter in human studies and suggests that much of human operant schedule performance may not be under the control of the programmed contingencies but may be instruction-controlled. Lowe (1979) also argues that experimental instructions are important but, in addition, he presents evidence to show that it is the capacity of human subjects to formulate their own descriptions of the contingencies in such a way that these descriptions function as rules governing their behavior that results in their performing differently from animals; what subjects say to themselves is a pervasive and influential source of stimulus control even when experimental instructions are minimized. Studies of FI performance in adult humans by Lowe, Harzem, and Bagshaw (1978) and Lowe, Harzem, and Hughes (1978) have shown that when interference from covert "self-instructions" is attenuated, response patterning is scalloped and relationships between different response measures and schedule value are very similar to those observed in animal performance on FI schedules.

If, as these accounts suggest, human subjects' verbal behavior is a variable that accounts for major differences in human and animal operant performance, then a number of predictions can be made. One of these is that humans who have not yet acquired the skill of verbally describing the contingencies, i.e., infants, will behave like animals rather than like adult humans on schedules of reinforcement. This prediction was tested in the present study, which investigated the performance of young infants on FI schedules.

METHOD

Subjects

Two infants took part. Ann was aged 9 months and Jon 10 months at the start of the

experiment. They were recruited through a local children's nursery group.

Apparatus

The response device was a metal cylinder, 40 cm long and 11 cm in diameter, mounted on a wooden stand. The cylinder was placed within reach of the subject who sat in a high chair (Ann), or on his mother's knee (Jon) (see Figure 2). When the cylinder was touched, an electronic touch-switch was activated and the response was registered by an Apple II micro-computer. Each operation of the touch-switch produced an audible click. Reinforcer delivery was signaled by a brief tone from the micro-computer, according to the particular schedule in operation.

Procedure

Responding was shaped by the method of successive approximations and each cylinder-touch was reinforced in the first two sessions. Subsequently, reinforcers were presented on FI schedules, ranging in value from 10 to 50 sec. Schedule values were changed when inspection of the records showed responding to be stable over three consecutive sessions (see Table 1). It was possible to conduct only three sessions with Jon on the FI 50-sec schedule, and hence the stability criterion was not met in this condition. Sessions normally lasted until 12 to 30 reinforcers had been delivered, depending, in part, upon schedule value but also upon other factors, such as nappy-wetting and various minor ailments that are inevitable features of

infant research. Sessions were conducted on most weekdays in the children's homes.

Our preliminary work had indicated that there was considerable individual variation among infants with respect to the events that could function as reinforcers; for example, feeding routines in some homes would either facilitate or rule out the use of food as a reinforcer. We relied upon parents for initial guidance as to suitable reinforcers. For Jon, the reinforcer consisted of small snack items, i.e., pieces of fruit, bread, and candy; for Ann it was 4 sec of music played on a variety of small music boxes.

RESULTS

Figure 3 shows individual cumulative records from sessions early in the development of FI 20-sec performance. In the case of Ann the initial sessions were characterized by bursts of responding immediately following reinforcement; these bursts were then followed by long periods of nonresponding and the next response was then reinforced. Long pauses, exceeding the FI values, were also present in Jon's earlier sessions. The response rates of both subjects increased in later sessions and a pause-respond pattern developed following reinforcement. Both the negatively accelerated responding in the course of the fixed interval observed in the early sessions and the gradual emergence of the final FI pattern (Figure 4) over several sessions, are characteristic of animal performance but have not been reported in previous human studies; in the latter the final form of responding is often established very quickly in the first one or two sessions

Table 1

Number of sessions conducted on each schedule value and standard deviation of mean postreinforcement pauses for each subject. The order of schedule values is shown from top to bottom.

FI Value (seconds)	Subject	Sessions	Standard Deviation (seconds)
20	ANN	10	4.8
10		10	1.5
30		6	5.4
20	JON	18	6.0
30		11	7.0
10		11	3.6
50		3	—



Fig. 2. Subject seated in a high chair with the response device (metal cylinder) in position.

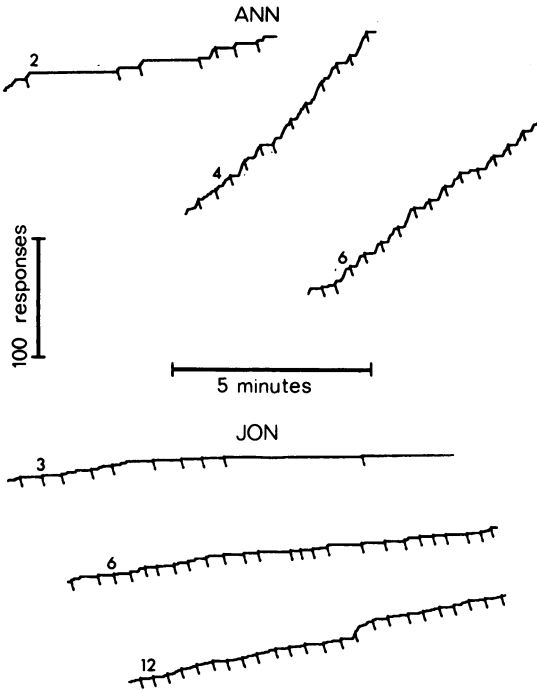


Fig. 3. Cumulative records of responding for each infant from some of the early sessions on FI 20-sec. The number adjacent to each record indicates the session from which the record was obtained.

(Ferster & Skinner, 1957; Lowe, Harzem, & Hughes, 1978; Weiner, 1969).

The final form of responding on FI 20-sec is shown in Figure 4, which presents cumulative records obtained from the final sessions on each schedule value. These records show that the predominant response pattern consisted of a pause after reinforcement followed by an accelerated rate of responding that terminated when the next reinforcement was delivered. This is the "scalped" pattern that is characteristic of animal performance on FI schedules but is remarkably elusive in the literature on the performance of adult humans and children aged 4 and over (DeCasper & Zeiler, 1972; Leander et al., 1968; Long et al., 1958; Lowe, 1979; Matthews et al., 1977; Weiner, 1969; Zeiler & Kelley, 1969).

Sensitivity to the schedule parameters is clearly evident in the cumulative records. It can also be assessed by other quantitative measures of performance such as rate of responding and duration of postreinforcement pause. In the case of animals, when FI value is increased (i) the mean duration of the postreinforcement pause increases, (ii) relative postreinforcement pause, i.e., the pause expressed as

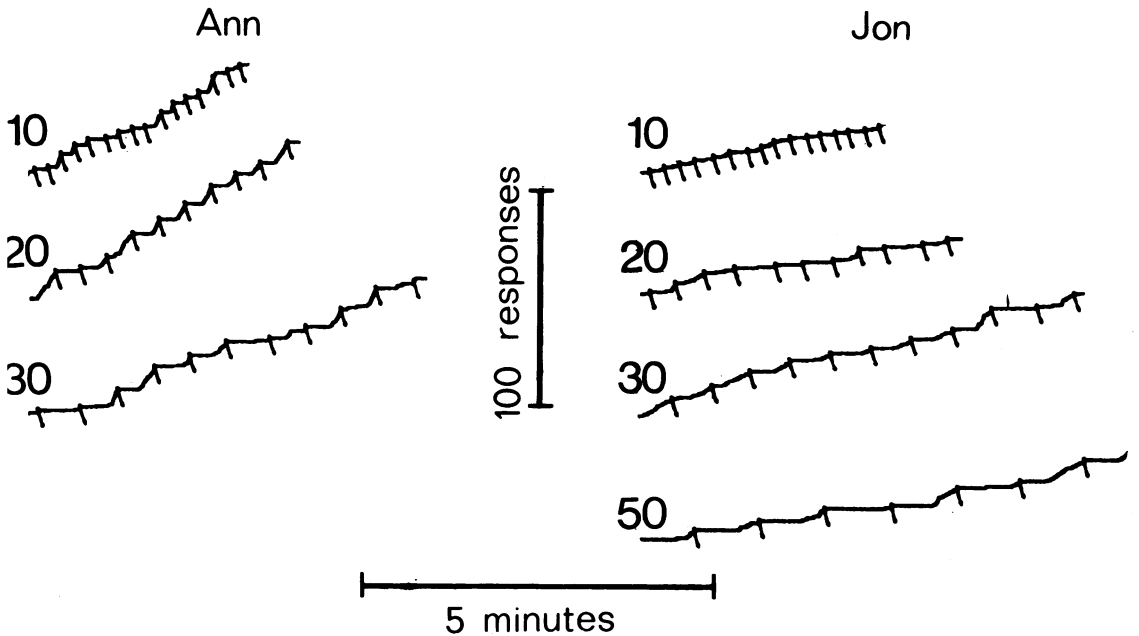


Fig. 4. Cumulative records of responding for each infant on FI 10-, 20-, and 30-sec and, in the case of Jon, FI 50-sec. The cumulative pen was offset with each reinforcement. With the exception of Jon's record on FI 50-sec, the records are from the final sessions on each schedule value (see text).

a proportion of schedule value, declines, and (iii) running rate, i.e., response rate calculated by excluding the postreinforcement pause, declines (Lowe et al., 1979; Skinner, 1938). Infant operant behavior showed the same relationships. The top part of Figure 5 shows pause data as a function of FI value for both subjects. The left panel shows mean postreinforcement pause durations (see Table 1 for standard deviations); the right panel shows the relative pause. As only three sessions were conducted with Jon on FI 50-sec, data from this condition are not included in this and subsequent analyses, which are all based upon data averaged over the last three sessions of stable responding on each schedule value. The mean postreinforcement pause of both subjects increased, and relative postreinforcement pause decreased, as functions of FI value. The lower panel of Figure 5 shows that the running rates of both subjects declined as a function of increasing FI value.

A detailed picture both of response patterning and of schedule sensitivity is provided by Figure 6. This shows for each subject the first

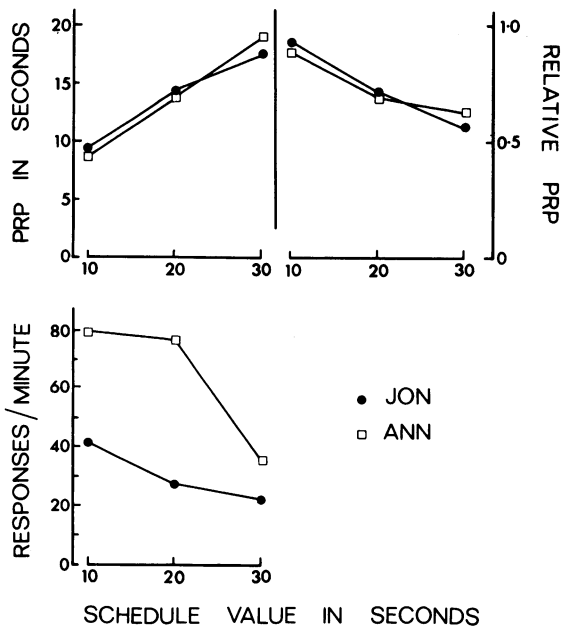


Fig. 5. Mean duration and relative duration of postreinforcement pause (PRP) for each infant as a function of schedule value (top panels). Relative duration was calculated as a proportion of the FI value. Running rates (i.e., response rates calculated by excluding postreinforcement pauses) as functions of schedule value are shown in the lower panel. Data are from the last three sessions on each schedule value.

nine successive mean interresponse times at each schedule value. For both subjects, on all FI values, successive interresponse times decreased in the course of the fixed interval, showing that the gradual acceleration of responding observed in the cumulative records was a consistent phenomenon present in all conditions. The considerable sensitivity of infant behavior to the schedule parameter was shown in the positive relation between interresponse time at each ordinal position and FI value—the only reversal being the case where Ann's second interresponse time was longer on FI 10-sec than on FI 20-sec. Functions of this kind have consistently been obtained in animal studies but not previously with human subjects (Dews, 1978; Lowe & Harzem, 1977; Lowe, 1979; but see also Lowe, Harzem, & Bagshaw, 1978, and Lowe, Harzem, & Hughes, 1978).

DISCUSSION

The present findings indicate that for human infants, the effects of reinforcement on behavior are indistinguishable from those well documented in the literature on animal learning. This is true of both response patterning and sensitivity to the FI parameter. The close correspondence between the schedule performance of infants and animals, and the marked contrast with performance of older children and adults, supports the suggestion that the development of verbal behavior may have a profound influence upon the rest of human learning (Hefferline, Keenan, & Harford, 1959; Lowe, 1979; Luria, 1961; Mead, 1934; Skinner, 1957, 1969, 1974; Sokolov, 1972). Hence, previous human operant studies may not have been able to produce findings similar to those of the present experiment because they used subjects with well-established verbal behavior that interfered with direct control by the reinforcing contingencies. The youngest subjects in previous human operant studies by Long et al., 1958, DeCasper and Zeiler, 1972, and Zeiler and Kelley, 1969, were at least four years old and stable FI performance was of either the high- or low-rate type characteristic of adult performance. Long et al. attempted to employ younger subjects but found that these children refused to stay in the experimental cubicles for more than a few minutes, a problem that was obviated in the present study by

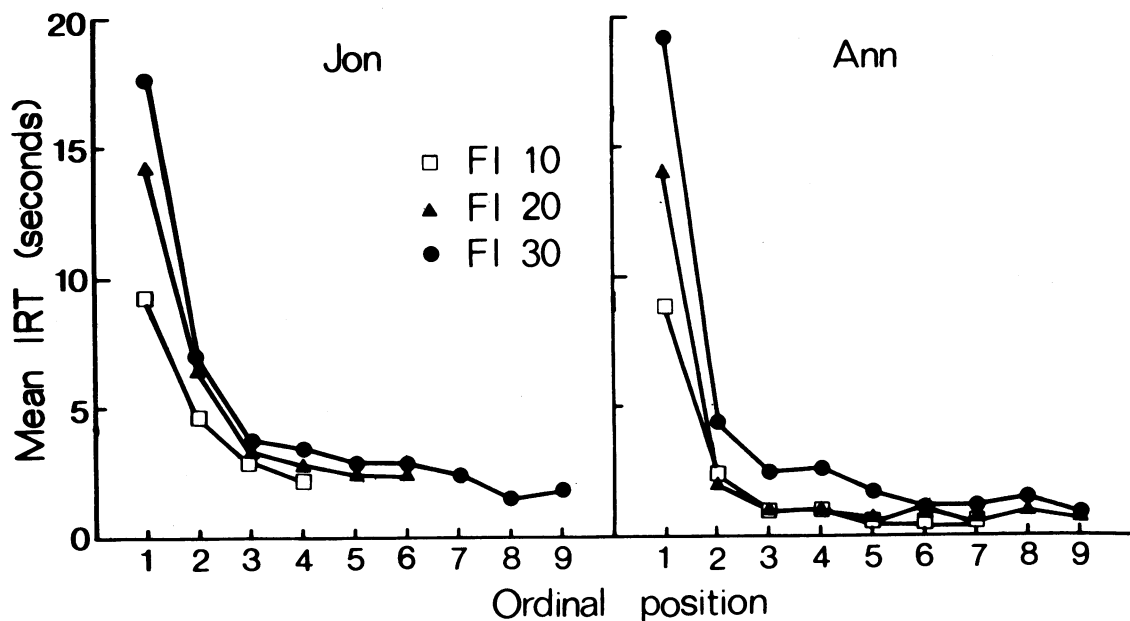


Fig. 6. Mean duration of interresponse times on each schedule value plotted against ordinal position in the interreinforcement interval. Data are from the last three sessions on each schedule value.

conducting sessions in surroundings familiar to the children.

Clearly, any comprehensive analysis of human operant performance will have to account for verbal behavior itself and describe the reinforcement contingencies that produce, for example, self-tacting behavior (see Skinner, 1957, p. 138). But the present evidence, together with the findings from a number of recent studies (cf. Bentall & Lowe, 1982; Duvinsky & Poppen, 1982; Horne & Lowe, 1982; Lowe, 1979, in press; Poppen, 1982), suggests that verbal behavior can, and does, serve a discriminative function that alters the effects of other variables such as scheduled reinforcement. Unlike animals, most humans are capable of describing to themselves, whether accurately or inaccurately, environmental events and the ways in which those events impinge upon them; such descriptions may greatly affect the rest of their behavior (Skinner, 1969, 1974; Sokolov, 1972). To ignore the role of covert verbal stimuli, as is customary in many human studies, simply because they are not publicly observable, is to ignore much of what determines human behavior and has little in common with radical behaviorist philosophy (cf. Lowe, in press; Skinner, 1974).

An analysis of the controlling functions of verbal behavior in human learning could have

far-reaching implications for basic research and clinical applications such as behavior modification (see, for example, Lowe & Higson, 1981, and the work of Meichenbaum, 1977, on self-instructional training). If, as the evidence of this and other studies suggests, operant performance is transformed by the development of verbal behavior, then a detailed investigation should be conducted into the ways in which verbal control is established and the ways it affects basic learning phenomena such as discrimination, generalization, and response maintenance. Despite Skinner's (1957) theoretical lead, few studies of this nature have so far been conducted and little is known about the characteristics of verbal behavior that control other operant performance. The schedule procedures and dependent variable measures employed in the present study, for example, could be used to assess (i) the role of specific characteristics of natural language development as they affect on-going operant performance, and (ii) the effects of instructional interventions, including experimenter-arranged verbal instructions and "self-instruction," relating to the reinforcement contingencies (cf. Bentall & Lowe, 1982). Research along these lines should not only help to establish the conditions responsible for the metamorphosis of infants' operant behavior into that of older

children and adults, but should also contribute to our understanding of what many have argued to be the "unique achievement" of humans, namely, the use of verbal behavior to control their interactions with the environment (Luria, 1961; Skinner, 1957, 1974; Terrace & Bever, 1980).

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