

Making Sense of Sensitivity in the Human Operant Literature

Gregory J. Madden
University of Vermont

Philip N. Chase and James H. Joyce
West Virginia University

Human operant behavior is often said to be controlled by different variables or governed by different processes than nonhuman operant behavior. Support for this claim within the operant literature comes from data suggesting that human behavior is often insensitive to schedules of reinforcement to which nonhuman behavior has been sensitive. The data that evoke the use of the terms *sensitivity* and *insensitivity*, however, result from both between-species and within-subject comparisons. We argue that because sensitivity is synonymous with experimental control, conclusions about sensitivity are best demonstrated through within-subject comparisons. Further, we argue that even when sensitivity is assessed using within-subject comparisons of performance on different schedules of reinforcement, procedural differences between studies of different species may affect schedule performance in important ways. We extend this argument to age differences as well. We conclude that differences across populations are an occasion for more precise experimental analyses and that it is premature to conclude that human behavior is controlled by different processes than nonhuman behavior.

Key words: humans, sensitivity, schedules of reinforcement, concurrent schedules, interspecies continuity

A great deal has been written about differences between human and non-human sensitivity to schedules of reinforcement (e.g., Baron & Galizio, 1983; Cerutti, 1989; Galizio, 1979; Kaufman, Baron, & Kopp, 1966; Lowe, 1979; Shimoff, Catania, & Matthews, 1981; Skinner, 1966). Some have argued that because human and nonhuman behavior is affected in different ways by seemingly comparable schedule contingencies, different principles are required for accurate accounts of human and nonhuman behavior (e.g., Brewer, 1974; Horne &

Lowe, 1996; Lowe, 1979). Frequently the new principles called for are those related to verbal behavior. For example, Lowe and Horne (1996) concluded that "(a) the performance of verbally able humans on schedules of reinforcement, including concurrent schedules, differed greatly from that observed in nonhuman species, and that (b) a key variable in bringing about these differences was human subjects' ability to specify the contingencies verbally and to formulate their own rules for responding" (p. 315). Consistent with this argument, a number of definitions of rule-governed behavior have been presented that include schedule insensitivity as a critical feature (Catania, Shimoff, & Matthews, 1989; Cerutti, 1989; Shimoff et al., 1981).

These arguments are important because they suggest that human behavior, at least that which is rule governed, is not sensitive to changes in schedules of reinforcement. We find it difficult to agree with this conclusion. Our review of the human operant literature reveals two potentially conflicting definitions of the term *sensitivity* (we assume

This work was supported by NIDA Grant 5-R01-DA06526-08.

Portions of this article were written as the first author's conceptual preliminary examination while a doctoral student at West Virginia University. We are grateful to Margaret Vaughan and several anonymous reviewers who provided insightful comments on the manuscript. James Joyce is now at the Continuous Learning Group, Jamesville, Virginia.

Address correspondence and reprint requests to Gregory J. Madden, Human Behavioral Pharmacology Laboratory, University of Vermont, 38 Fletcher Place, Burlington, Vermont 05401-1419.

throughout that sensitivity and insensitivity describe opposite ends of a continuum of verbal responses that an experimenter makes in the presence of a set of behavioral data). According to one definition, human behavior is schedule sensitive only when it resembles schedule-sensitive nonhuman behavior. The other defines sensitivity as a change in behavior following a contingency change. We believe that when these two definitions are pinpointed and applied to the findings of the human operant literature, the conclusions about sensitivity and insensitivity are not as clear as suggested by Lowe and Horne (1996) or others. Therefore, the present paper will (a) distinguish more explicitly these two definitions of schedule sensitivity, (b) review some confusions apparently generated by these definitions, (c) offer alternative methods of describing the two sets of behavioral data that evoke the verbal response "sensitivity," and (d) discuss some of the implications of these proposed methods of description.

Definitions of Sensitivity and Insensitivity

Between-species comparisons. When human behavior resembles schedule-typical nonhuman behavior maintained by similar contingencies, researchers frequently describe the human behavior as being "sensitive" to the operative contingencies (Navarick, Bernstein, & Fantino, 1990). Conversely, if the human behavior is atypical of nonhumans, the probability of labeling it "insensitive" is increased (for a brief summary of this practice in the human operant literature, see Baxter & Schlinger, 1990). We will refer to this relation between human and nonhuman behavior as the *between-species comparison* definition of sensitivity. For example, Lowe, Harzem, and Bagshaw (1978) suggested that observing-response tasks may engender more sensitive human fixed-interval (FI) performances because the behavior obtained when these tasks are employed more closely

resembled the pause-respond patterns of nonhumans (a between-species comparison). Similarly, B. Matthews, Shimmoff, Catania, and Sagvolden (1977) described human performances under multiple, concurrent, and FI schedules as being insensitive when performances were divergent from response patterns typifying nonhuman behavior under similar conditions. Like Lowe et al., Matthews and colleagues suggested that observing-response procedures were an effective means of improving human schedule sensitivity, "at least in the sense that they generate scalloping in human FI responding" (p. 454). When Matthews et al. discussed the relation between insensitivity and instructed performances, they contended that manipulating schedule contingencies can reveal the influence of instructions because "the effects of the natural contingencies are known, therefore providing a baseline against which instructional effects can be assessed" (p. 465). One interpretation of this position is that researchers know what sensitive performances look like: They look like schedule-typical nonhuman response patterns. Thus, when humans fail to respond like nonhumans, the performance is often described as being insensitive to the programmed consequences.

The B. Matthews et al. (1977) study is not atypical. Much attention has been given to comparing human and nonhuman patterns of behavior on schedules of reinforcement, and some of the most influential work in this area has compared human schedule behavior across age groups to nonhuman performances (e.g., Bentall, Lowe, & Beasty, 1985; Lowe, Beasty, & Bentall, 1983). In these studies, preverbal infants' response patterns have most resembled the scalloped and pause-respond patterns viewed as typical of nonhumans on FI schedules (although see Hyten & Madden, 1993, for a reanalysis of this data). The response patterns of older, language-able children in these studies have been more comparable to adult human than to

nonhuman FI-maintained behavior. The impact of these studies on the debate concerning human schedule sensitivity is summarized by Baxter and Schlinger (1990): "When schedule sensitivity is assessed by comparisons with nonhuman performances, only the performances of preverbal children will resemble those of nonhumans" (pp. 263–264). Such between-species comparisons can be contrasted with the other means of defining sensitivity: within-subject comparisons.

Within-subject comparisons. The other class of behavioral data that leads to using the term *sensitivity* is composed of comparisons made within a subject: The experimenter compares the behavior of a single subject in one condition with the behavior of the same subject under another condition. Behavior is described as being sensitive when a stable pattern or rate of behavior changes systematically following a contingency change. Conversely, stable behavior that fails to change with the contingency change is frequently described as being insensitive. We will refer to this definition as the *within-subject comparison* definition of sensitivity.

The human operant literature is replete with examples of within-subject comparisons in which behavior is described as being sensitive or insensitive to contingency changes (e.g., Baum, 1975; Buskist, Bennett, & Miller, 1981; Shimoff, Matthews, & Catania, 1986). Shimoff et al. (1986), for example, described human performances as insensitive to a contingency change when response rates failed to change after the reinforcement contingency was shifted from a tandem random-interval (RI) differential-reinforcement-of-low-rate (DRL) schedule to a simple RI schedule.

The within-subject comparison definition of sensitivity has also been employed in several versions of Herrnstein's (1970) matching law. For example, the sensitivity parameter of Baum's (1974) generalized matching equation is interpreted as a quantitative

measure of sensitivity. When the generalized matching equation is applied to concurrent-schedule performances, the sensitivity parameter quantifies the extent to which behavior changes with changes in the relative frequency of reinforcement. Sensitivity parameter values approximating zero indicate that response allocation to the two reinforcement sources is affected little by changes in the ratio of reinforcers obtained from the sources. So, for example, if the ratio of obtained reinforcers on the two schedules is initially 1:1 and then changes to 5:1, but the response ratio remains at 1:1 throughout, the exponent of the generalized matching equation will equal zero, indicating complete insensitivity to the change in consequences. If, however, the response ratio is initially 1:1 and then changes to 5:1 following the change in the ratio of obtained reinforcers, the response ratio has changed proportionally with the reinforcer change. The latter case yields a sensitivity parameter of 1.0 in the generalized matching equation. If behavior were to change in the opposite direction (i.e., from a response ratio of 1:1 to 1:5) following the same contingency change, then behavior would likewise be sensitive to this change and the sensitivity parameter would equal -1.0 . The case of negative sensitivity parameter values, although rarely observed, demonstrates that the sensitivity parameter quantifies behavior change following a change in contingencies of reinforcement, not changes in a particular direction. The sensitivity parameter is not a measure of the extent to which behavior resembles typical nonhuman performances (nonhumans are usually undersensitive with exponent values between 0.8 and 0.9; Baum, 1979; Wearden & Burgess, 1982) and therefore is inconsistent with the between-species comparison definition of sensitivity. This measure is a very precise example of the within-subject comparison definition of sensitivity, as specified above.

Confusions Created by Multiple Definitions of Sensitivity

These two uses of the term *sensitivity* are confusing because the same set of behavioral data can be viewed as being sensitive or insensitive depending on which definition is used. If a dimension of steady-state behavior (e.g., rate or postreinforcement pause duration) repeatedly covaries with dimensions of the reinforcement schedules (e.g., mean interreinforcement intervals) and the experiment is apparently free of confounding variables, then contingency control has been demonstrated and the behavior could be labeled sensitive to the contingency change. If the two steady-state performances, however, are unlike those of nonhumans under similar contingencies, researchers might conclude that the behavior is insensitive to the operative contingencies despite the observation that it covaried with the contingency change.

Data reported by Weiner (1969) provide an example of this confusion. In Weiner's experiments, human subjects given a history of reinforcement on a DRL schedule produced response rates and postreinforcement pauses that covaried with FI schedule values (Experiment 3). Thus, behavior of subjects with a DRL history was controlled by FI contingencies, but the response patterns observed did not resemble those typical of nonhumans under similar conditions; instead, one or two responses were made at the end of each interval. If nonhuman response patterns serve as a benchmark of sensitivity against which human behavior is compared, then this example of human behavior that was systematically affected by the contingency change would be described as being insensitive to that change. If the within-subject definition of sensitivity is applied to Weiner's data, however, the post-DRL behavior would be described as being sensitive to the FI contingencies. Weiner's data are not an isolated case. Within the rule-governance literature,

there are other examples of data that can be interpreted as insensitive if compared to nonhuman performances and sensitive if within-subject changes in performances serve as criteria (e.g., Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986).

Confusions Created by Between-Species Comparisons

The procedural similarity of experiments with nonhumans has led to a relatively good understanding of the variables that control nonhuman behavior. In addition, the procedures employed with nonhumans in separate laboratories are relatively consistent when compared with the array of procedures and reinforcers used with human subjects (see the Spring, 1988, special issue of *The Behavior Analyst*). The standard procedures used with nonhumans have resulted in a large literature showing that behavior is sensitive to parameters of reinforcement schedules. These data supported researchers' generalizations about nonhuman performances, like the FI scallop, that were subsequently compared to human behavior. Using the behavior of other species as a benchmark for human schedule sensitivity (between-species comparison definition), however, is confusing for at least three reasons.

First, "schedule-typical" nonhuman behavior may not be as typical as many suppose (Perone, Galizio, & Baron, 1988). For example, Figure 1 shows cumulative records from a single pigeon under "sustained reinforcement" on an FI 1-min schedule (reprinted from Ferster & Skinner, 1957, p. 157). The lower case letters are individual intervals highlighted by Ferster and Skinner across six sessions (A–F). Letters h, i, and k show break-and-run responding like that found by Weiner (1969) with humans. The remaining lower case letters show intervals in which the pigeon responded throughout the FI (other examples of this pattern could be occasionally highlighted throughout session records D and E as

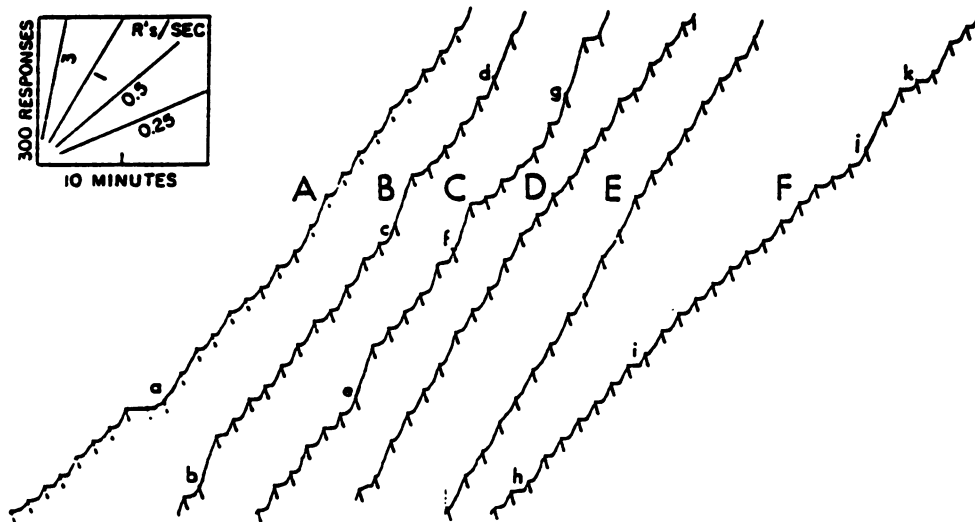


Figure 1. Cumulative records of pigeon behavior under an FI 1-min schedule of reinforcement (reprinted from Ferster & Skinner, 1957, p. 157). The capital letters A through F show response patterns from six individual sessions. The response patterns identified by lower case letters were highlighted by Ferster and Skinner as exceptions to the scalloping otherwise observed. The original figure caption read "Sustained reinforcement on FI 1."

well). Three other anomalous nonhuman FI response patterns that were observed frequently enough to warrant verbal description by Ferster and Skinner include the "knee," a negative or inverted scallop, and a single response at the end of the interval. These anomalous patterns bring into question how characteristic of nonhuman FI behavior the scallop or break-and-run patterns may be.

Second, viewing nonhuman behavior as a benchmark against which human behavior is compared is confusing because behavior is not always entirely consistent *between* nonhuman species. When rats respond at low rates on DRL schedules and pigeons respond at higher rates (e.g., Kramer & Rilling, 1970), which rate will researchers compare with humans under similar contingencies for the purpose of assessing sensitivity? Similar differences separate different species under multiple, concurrent, and fixed-time schedule contingencies, to name a few. Perone et al. (1988) have provided more examples of interspecies performance differences in nonhumans. These examples argue against holding a typical

or idealized pattern of nonhuman behavior as a benchmark against which human behavior is judged to be sensitive or insensitive to schedule contingencies.

Third, using the between-species definition of sensitivity rests on the inductive leap that procedures employed with humans and nonhumans that are *structurally* similar across species will be *functionally* similar as well. According to this logic, all experimental procedures that resemble those controlling nonhuman behavior must also control human behavior in the same manner. This conclusion, however, ignores the possibility that procedures that are structurally similar across experiments may produce functional differences across species. Particular arrangements of keys, reinforcer-delivery systems, deprivation conditions, and so forth have been used with particular species because they are well suited to the phylogenetic histories of the species or to the ontogenic history of the organism. When these same arrangements are used with another species, they may interfere with control by the variable of interest (e.g., changes in schedules of

reinforcement). A number of studies that have focused on making human operant procedures more functionally similar to nonhuman procedures have found human behavior to be highly sensitive to changing parameters of reinforcement (e.g., Barnes & Keenan, 1993; Baron & Kaufman, 1966; Baum, 1975; Baxter & Schlinger, 1990; Buskist & Miller, 1981; Galizio, 1979; Hyten, Madden, & Field, 1994; Joyce & Chase, 1990; LeFrancois, Chase, & Joyce, 1988; Logue, Forzano, & Tobin, 1992; Madden & Perone, in press; Schroeder & Holland, 1969; Torgrud & Holburn, 1990; Trenholme & Baron, 1975). In addition, other studies have found nonhuman behavior to more closely resemble human behavior when procedures were made to functionally resemble those frequently employed with human subjects (e.g., Jackson & Hackenberg, 1996; Wan-chisen, Tatham, & Mooney, 1989).

The argument that human and non-human behavior is governed by different processes has most recently focused on human sensitivity to concurrent variable-interval (VI) VI schedules (Horne & Lowe, 1993). Although Horne and Lowe have described conditions under which humans are insensitive to concurrent schedules, an experiment conducted by Madden and Perone (in press) suggests that this insensitivity may be the result of functional differences in procedures separating experiments with humans and nonhumans. Arguing that procedures typically employed with humans do not require subjects to observe the stimuli correlated with the concurrent-schedule alternatives, Madden and Perone manipulated the extent to which human subjects could make an observing response to produce these stimuli. Behavior was insensitive when subjects either could not or did not observe the schedule-correlated stimuli. Schedule sensitivity increased within the same subjects, however, when procedural changes were introduced that required the subjects to observe the stimuli to earn reinforcers. Thus, hu-

man schedule sensitivity increased when procedures were employed that appear to more closely resemble the functional characteristics of procedures used with nonhumans.

As noted above, some researchers have apparently assumed that the contingency changes employed in human and nonhuman operant experiments are functionally similar, and this has led them to suggest that instances of human schedule insensitivity call for new principles of behavior (e.g., Horne & Lowe, 1993; Lowe, 1979). An analogous instance of interspecies sensitivity differences currently exists in the non-human concurrent-schedule literature, but the scientific community's reaction has been rather different. Briefly, most nonhuman concurrent VI VI behavior is well described by the matching law (Herrnstein, 1970) with slight undermatching (for reviews see Bradshaw & Szabadi, 1988; de Villiers, 1977). Cows, however, are much less sensitive to concurrent schedules, in a manner not unlike human behavior under the same schedules (Foster, Temple, Robertson, Nair, & Poling, 1996; L. Matthews & Temple, 1979). Interestingly, no researchers have claimed (to our knowledge) that new principles of behavior are required to understand the behavior of cows, or that processes governing cow behavior also govern human behavior. Instead, efforts to understand sensitivity differences between cows and other nonhumans have been focused primarily on the procedural differences separating these experiments (e.g., Dougherty & Lewis, 1992; Foster et al., 1996; Rachlin, Kagal, & Battalio, 1980). We believe that the same strategy may be well suited to understanding instances of human insensitivity to schedules of reinforcement.

Toward a Definition of Sensitivity

As a first step toward a better definition of sensitivity, we propose that sensitivity is *not* determined by comparing human and nonhuman behavior.

Our previous arguments suggest that schedule-typical behavior is difficult to identify, and that there are many functional and structural differences in procedures used with different species. By arguing against the use of nonhuman benchmarks for determining sensitivity, however, we are not suggesting that researchers should ignore interspecies differences in behavior. Overlooking such differences may lead to inaccurate generalizations or predictions and to stifled research in areas mistakenly considered to be well understood. We think the term *interspecies replication* better describes the consistency of effect obtained across species than does the term *sensitivity*. The former term clearly specifies the behavioral data that evoke its use, leaving *sensitivity* to describe effects of the independent variable on individual behavior (Baxter & Schlinger, 1990). Thus, Weiner (1969) provided data that showed human sensitivity to the manipulated schedules but failed to demonstrate interspecies replication.

Our discussion of the between-species definition of human schedule sensitivity should not be viewed as an indictment of between-subjects comparisons for investigating the effects of experimental variables. Comparisons made between 2 human subjects exposed to different conditions (e.g., B. Matthews et al., 1977) or differing in subject characteristics (e.g., Bentall et al., 1985) but otherwise exposed to identical schedules of reinforcement are frequently employed in the human operant literature. This is particularly true in the rule-governance literature, in which subjects are frequently given different instructions and exposed to identical schedules of reinforcement. Although within-subject procedures offer the experimenter more power to detect the effects of independent variables, these between-subjects comparisons may be necessary either because providing instructions cannot be reversed or because subject variables cannot be manipulated within a subject. These comparisons, if done with

careful attention to controlling potential confounding variables, can contribute to our knowledge of procedural or subject variables that might contribute to insensitivity. The intent here, therefore, is not to criticize experiments using between-subjects comparison procedures; instead our focus is on the use of between-species comparisons as the basis for statements about human sensitivity and insensitivity to experimental variables.

Having parceled out the between-species definition of sensitivity, we are left with the following: Sensitivity is demonstrated when an experimental manipulation affects behavior in an orderly and replicable manner. Insensitivity describes a lack of behavior change following an experimental manipulation. As noted above, this within-subject definition of sensitivity is consistent with the definition of sensitivity within Baum's (1974) generalized matching equation. In fact, the sensitivity parameter within the matching law provides a precise quantitative measure of the *degree* of sensitivity. Another quantitative measure consistent with the within-subject definition of sensitivity is *elasticity of demand* (Hursh, 1980). Elasticity measures sensitivity of consumer demand (i.e., the rate at which reinforcers are obtained) to changing reinforcement magnitude or schedule parameters. In both cases, a form of experimental control is required in order to use the terms *sensitivity* or *elasticity*. Thus, sensitive behavior is synonymous with behavior under experimental control.

Two experiments provide examples of the above definitions of sensitivity, insensitivity, and interspecies replication. First, Baxter and Schlinger (1990) reported instances of sensitivity and interspecies replication in their study of children's response rates under random-ratio (RR) and RI contingencies. Behavior was sensitive to the schedule type because response rates were reliably higher under the RR schedule. The same data provide evidence for interspecies replication because nonhu-

mans also respond more rapidly on RR than RI schedules (e.g., Catania, Matthews, Silverman, & Yohalem, 1977).

Pierce, Epling, and Greer (1981) conducted an experiment in which human speech directed toward two confederates was verbally praised according to concurrent VI VI schedules. The first subject was insensitive to changes in the relative rate of praise given by each confederate (sensitivity parameter of the generalized matching equation, $a = -0.02$; where a indicates greater sensitivity as values deviate further from zero in either a positive or negative direction). That is, the first subject's speech was about equally distributed between confederates, despite one delivering more praise than another. Behavior of the third subject showed greater sensitivity than any other subject in the experiment ($a = -0.49$); however, sensitivity parameter values are typically positive in nonhumans. Thus, interspecies replication was not demonstrated by either of these subjects.

Implications of the Proposed Definitions

Perhaps one obvious implication of the proposed definition of *sensitivity* is that the term should not be viewed as being synonymous with some logically defined schedule-appropriate responding, matching, or maximizing. For example, the negative sensitivity parameter value reported by Pierce et al. (1981) is not an example of insensitivity, even though the negative value indicates that more behavior was allocated to the relatively leaner concurrent-schedule alternative. Although this subject obviously failed to maximize reinforcers while minimizing response output, the behavior was systematically affected by the different contingency changes imposed in the experiment. Because nonhumans nearly always allocate their behavior in the exact opposite fashion (i.e., they allocate more behavior to the relatively richer available schedule), this is an example of

failure to obtain interspecies replication. This difference, although it does not show sensitivity, strongly suggests careful consideration of the similarity of the procedures used across species. For example, in the Pierce et al. experiment in which negative sensitivity parameter values were observed, the investigators arguably used qualitatively different reinforcers by having social praise delivered by two different confederates. In animal experiments, reinforcers obtained from both concurrent schedules are typically of the same type (e.g., grain) and come from the same location (e.g., a single food hopper).

Some readers may object to labeling a negative sensitivity parameter value as an instance of concurrent-schedule sensitivity because this behavior seems "irrational" in the economic sense of the word. From our view, however, irrationality has nothing to do with sensitivity. Behavior that changes systematically with changes in an independent variable suggests that a controlling variable has been isolated. If sensitive behavior also seems irrational, then the logic behind the rational explanation of the manipulated variables needs to be examined. In the Pierce et al. (1981) experiment, for example, the possibility exists that the negative sensitivity parameter value is due to the existence of a complementary relation between the two reinforcers (e.g., Allison, 1983; Bickel, DeGrandpre, & Higgins, 1995; Rachlin et al., 1980). When a complementary relation exists between two different reinforcers (e.g., between food and water), the reinforcers lose some of their efficacy if they are not obtained at a constant ratio (e.g., two units of food to every one unit of water consumed). The subject in question in the Pierce et al. experiment may have allocated more behavior to the relatively leaner schedule of reinforcement because deviating from a constant ratio of reinforcers obtained from the two confederates (e.g., 1:1) would have resulted in a loss of reinforcer efficacy. These speculations are not intended to

serve as a definitive analysis, but instead simply point out that despite their irrationality, any instance of behavioral sensitivity is an interesting phenomenon worthy of further study (e.g., Skinner, 1956).

A second implication of the proposed definitions is that instances of human insensitivity to changing schedules of reinforcement *may* have theoretical significance if the experiments that verify this insensitivity have manipulated the full parametric range of the variable of interest, and if nonhuman behavior is sensitive to these changes (note that we are interested in interspecies *replicability of sensitivity*, rather than human and nonhuman behavior being identical). Before the investigator may assert a discontinuity between human and nonhuman behavior, however, discontinuities between the procedures employed with humans and nonhumans must be experimentally investigated. The list of potentially important procedural differences is likely to be formidable and represents a challenging task for the scientist who seeks to understand interspecies discontinuity. Indeed, the list of possible procedural differences is huge, and a researcher biased toward seeing interspecies continuity may be able to create a seemingly endless list of these variables, just as a researcher biased toward identifying instances of discontinuity may be able to provide an endless list of reasons discounting the validity of these procedural concerns. Definitive demonstration of interspecies continuity or lack of continuity may be an impossible task, rendering the positions as opposing philosophical assumptions.

We are not interested in limiting the debate fostered by such opposing positions. The behavior of scientists, like the behavior of members of all groups, can be viewed in terms of its variability. There are those who take extreme positions on each end of any issue and those who take moderate positions between these ends. We suspect all of these various positions are supported

by the contingencies of doing science, and all may be necessary in order to find what works.

The final implication of the proposed definitions is that the difficulties associated with using between-species comparisons to determine schedule sensitivity frequently appear equally applicable to comparisons made between human subjects of different stages of development (e.g., Bentall et al., 1985; Darcheville, Rivière, & Wearden, 1993). That is, differences that may be attributed to developmental differences separating subject groups might also be attributable to procedural differences separating the groups. For example, in the Bentall et al. (1985) study, differences in FI schedule-maintained response patterns observed across the infant and older developmental groups may have been a function of developmental differences (e.g., language capacity), but they may have also been due to differences in experimental settings, manipulanda, and reinforcers. Whether these structural differences in procedure amount to functional differences affecting behavior is an empirical question requiring further experimental analysis; the current data do not adequately support either position.

Conclusions

Few issues in the experimental analysis of behavior are more important than the generality of operant principles to the behavior of humans. Because the adoption and use of operant contingencies to change human behavior hinge upon successful demonstrations of human contingency sensitivity both in and outside the laboratory, it is critical that agreed-upon definitions of sensitivity and insensitivity are applied to these data. We have argued that a criterion of sensitivity based on between-species comparisons has led to a number of confusions; perhaps most notably that unexplored functional differences may separate structurally similar human and nonhuman experimen-

tal procedures, and that this unexplored status renders premature many conclusions about the generality (or the lack of generality) of the processes governing nonhuman behavior to the behavior of humans. Thus, we recommend using a within-subject definition of schedule sensitivity, and separately describing the extent to which interspecies replications are demonstrated.

Recognizing that insensitivity is synonymous with failure of experimental control suggests that when there is reason to believe that the behavior of nonhuman organisms is sensitive to a particular independent variable and within-session manipulations reveal that human behavior is insensitive to this variable, then in these cases the experimenter should focus on procedural factors that may have led to insensitivity. Only after these factors have been ruled out would a finding of insensitivity be interpreted as having theoretical significance, and then only within a carefully argued network of findings.

Although we recommend within-subject experiments for assessing sensitivity to the effects of an independent variable, we recognize the importance of between-species and between-subjects comparisons. Between-species comparisons are important in assessing the interspecies generality of behavioral principles and in understanding how phylogenetic differences affect the behavior of different species. Likewise, between-subjects comparisons are important in assessing the effects of subject variables and variables that are suspected of having irreversible effects. When using these methodologies, however, the researcher must be careful to avoid making statements about the sensitivity or insensitivity of a particular species' or subject's behavior based on these comparisons alone.

REFERENCES

Allison, J. (1983). *Behavioral economics*. New York: Praeger.

Barnes, D., & Keenan, M. (1993). Concurrent activities and instructed human fixed-interval

- performance. *Journal of the Experimental Analysis of Behavior*, 59, 501-520.
- Baron, A., & Galizio, M. (1983). Instructional control of human operant behavior. *The Psychological Record*, 33, 495-520.
- Baron, A., & Kaufman, A. (1966). Human free-operant avoidance of "time out" from monetary reinforcement. *Journal of the Experimental Analysis of Behavior*, 9, 557-565.
- Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior*, 22, 231-242.
- Baum, W. M. (1975). Time allocation in human vigilance. *Journal of the Experimental Analysis of Behavior*, 23, 45-53.
- Baum, W. M. (1979). Matching, undermatching, and overmatching in studies of choice. *Journal of the Experimental Analysis of Behavior*, 32, 269-281.
- Baxter, G. A., & Schlinger, H. (1990). Performance of children under a multiple random-ratio random-interval schedule of reinforcement. *Journal of the Experimental Analysis of Behavior*, 54, 263-271.
- Bentall, R. P., Lowe, C. F., & Beasty, A. (1985). The role of verbal behavior in human learning: II. Developmental differences. *Journal of the Experimental Analysis of Behavior*, 43, 165-181.
- Bickel, W. K., DeGrandpre, R. J., & Higgins, S. T. (1995). The behavioral economics of concurrent drug reinforcers: A review and reanalysis of drug self-administration research. *Psychopharmacology*, 118, 250-259.
- Bradshaw, C. M., & Szabadi, E. (1988). Quantitative analysis of human operant behavior. In G. Davey & C. Cullen (Eds.), *Human operant conditioning and behavior modification* (pp. 225-259). Chichester, England: Wiley.
- Brewer, W. F. (1974). There is not convincing evidence for operant or classical conditioning in adult humans. In W. B. Weimer & D. J. Palermo (Eds.), *Cognition and symbolic processes* (pp. 1-42). Hillsdale, NJ: Erlbaum.
- Buskist, W. F., Bennett, R. H., & Miller, H. L. (1981). Effects of instructional constraints on human fixed-interval performance. *Journal of the Experimental Analysis of Behavior*, 35, 217-225.
- Buskist, W. F., & Miller, H. L. (1981). Concurrent operant performance in humans: Matching when food is the reinforcer. *The Psychological Record*, 31, 95-100.
- Catania, A. C., Matthews, B. A., Silverman, P. J., & Yohalem, R. (1977). Yoked variable-ratio and variable-interval responding in pigeons. *Journal of the Experimental Analysis of Behavior*, 28, 155-161.
- Catania, A. C., Shimoff, E., & Matthews, B. A. (1989). An experimental analysis of rule-governed behavior. In S. C. Hayes (Ed.), *Rule-governed behavior: Cognition, contingencies, and instructional control*, (pp. 119-150). New York: Plenum Press.
- Cerutti, D. T. (1989). Discrimination theory of

- rule-governed behavior. *Journal of the Experimental Analysis of Behavior*, 51, 259–276.
- Darcheville, J. C., Rivière, V., & Wearden, J. H. (1993). Fixed-interval performance and self-control in infants. *Journal of the Experimental Analysis of Behavior*, 60, 239–254.
- de Villiers, P. A. (1977). Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 233–287). Englewood Cliffs, NJ: Prentice Hall.
- Dougherty, D. M., & Lewis, P. (1992). Matching by horses on several concurrent variable-interval schedules. *Behavioural Processes*, 26, 69–76.
- Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement*. New York: Appleton-Century-Crofts.
- Foster, T. M., Temple, W., Robertson, B., Nair, V., & Poling A. (1996). Concurrent-schedule performance in dairy cows: Persistent undermatching. *Journal of the Experimental Analysis of Behavior*, 65, 57–80.
- Galizio, M. (1979). Contingency-shaped and rule-governed behavior: Instructional control of human loss avoidance. *Journal of the Experimental Analysis of Behavior*, 31, 53–70.
- Hayes, S. C., Brownstein, A. J., Zettle, R. D., Rosenfarb, I., & Korn, Z. (1986). Rule-governed behavior and sensitivity to changing consequences of responding. *Journal of the Experimental Analysis of Behavior*, 45, 237–256.
- Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior*, 13, 243–266.
- Horne, P. J., & Lowe, C. F. (1993). Determinants of human performance on concurrent schedules. *Journal of the Experimental Analysis of Behavior*, 59, 29–60.
- Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior*, 65, 185–241.
- Hursh, S. R. (1980). Economic concepts for the analysis of behavior. *Journal of the Experimental Analysis of Behavior*, 34, 219–238.
- Hyten, C., & Madden, G. J. (1993). The scallop in human fixed-interval research: A review of problems with data description. *The Psychological Record*, 43, 471–500.
- Hyten, C., Madden, G. J., & Field, D. P. (1994). Exchange delays and impulsive choice in adult humans. *Journal of the Experimental Analysis of Behavior*, 62, 225–233.
- Jackson, K., & Hackenberg, T. D. (1996). Token reinforcement, choice, and self-control in pigeons. *Journal of the Experimental Analysis of Behavior*, 66, 29–49.
- Joyce, J. H., & Chase, P. N. (1990). Effects of response variability on the sensitivity of rule-governed behavior. *Journal of the Experimental Analysis of Behavior*, 54, 251–262.
- Kaufman, A., Baron, A., & Kopp, R. E. (1966). Some effects of instructions on human operant behavior. *Psychonomic Monograph Supplements*, 1, 243–250.
- Kramer, T. J., & Rilling, M. (1970). Differential-reinforcement-of-low-rates: A selective critique. *Psychological Bulletin*, 74, 225–256.
- LeFrancois, J. R., Chase, P. N., & Joyce, J. H. (1988). The effects of a variety of instructions on human fixed-interval performance. *Journal of the Experimental Analysis of Behavior*, 49, 383–393.
- Logue, A. W., Forzano, L. B., & Tobin, H. (1992). Independence of reinforcer amount and delay: The generalized matching law and self-control in humans. *Learning and Motivation*, 23, 326–342.
- Lowe, C. F. (1979). Determinants of human operant behaviour. In M. D. Zeiler & P. Harzem (Eds.), *Reinforcement and the organization of behavior* (pp. 159–192). New York: Wiley.
- Lowe, C. F., Beasty, A., & Bentall, R. P. (1983). The role of verbal behavior in human learning: Infant performance on fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 39, 157–164.
- Lowe, C. F., Harzem, P., & Bagshaw, M. (1978). Species differences in temporal control of behavior II: Human performance. *Journal of the Experimental Analysis of Behavior*, 29, 351–361.
- Lowe, C. F., & Horne, P. J. (1996). Reflections on naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior*, 65, 315–340.
- Madden, G. J., & Perone, M. (in press). Human sensitivity and insensitivity to concurrent schedules of reinforcement: Effects of observing schedule-correlated stimuli. *Journal of the Experimental Analysis of Behavior*.
- Matthews, B. A., Shimoff, E., Catania, A. C., & Sagvolden, T. (1977). Uninstructed human responding: Sensitivity to ratio and interval contingencies. *Journal of the Experimental Analysis of Behavior*, 27, 453–467.
- Matthews, L. R., & Temple, W. (1979). Concurrent schedule assessment of food preference in cows. *Journal of the Experimental Analysis of Behavior*, 32, 245–254.
- Navarick, D. J., Bernstein, D. J., & Fantino, E. (1990). The experimental analysis of human behavior. *Journal of the Experimental Analysis of Behavior*, 54, 159–162.
- Perone, M., Galizio, M., & Baron, A. (1988). The relevance of animal-based principles in the laboratory study of human operant conditioning. In G. Davey & C. Cullen (Eds.), *Human operant conditioning and behavior modification* (pp. 59–85). Chichester, England: Wiley.
- Pierce, W. D., Epling, W. F., & Greer, S. M. (1981). Human communication and the matching law. In C. M. Bradshaw, E. Szabadi, & C. F. Lowe (Eds.), *Quantification of steady-state operant behavior* (pp. 345–348). Amsterdam: Elsevier.
- Rachlin, H., Kagel, J. H., & Battalio, R. (1980).

- Substitutability in time-allocation. *Psychological Bulletin*, 87, 355–374.
- Schroeder, S. R., & Holland, J. G. (1969). Reinforcement of eye movement with concurrent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 12, 897–903.
- Shimoff, E., Catania, A. C., & Matthews, B. A. (1981). Uninstructed human responding: Sensitivity of low-rate performances to schedule contingencies. *Journal of the Experimental Analysis of Behavior*, 36, 207–220.
- Shimoff, E., Matthews, B. A., & Catania, A. C. (1986). Human operant performance: Sensitivity and pseudosensitivity to contingencies. *Journal of the Experimental Analysis of Behavior*, 46, 149–157.
- Skinner, B. F. (1956). A case history in scientific method. *American Psychologist*, 11, 211–233.
- Skinner, B. F. (1966). An operant analysis of problem-solving. In B. Kleinmuntz (Ed.), *Problem solving* (pp. 225–257). New York: Wiley.
- Torgrud, L. J., & Holburn, S. W. (1990). The effects of verbal performance descriptions on nonverbal operant responding. *Journal of the Experimental Analysis of Behavior*, 54, 273–291.
- Trenholme, I. A., & Baron, A. (1975). Immediate and delayed punishment of human behavior by loss of reinforcement. *Learning and Motivation*, 6, 62–79.
- Wanchisen, B. A., Tatham, T. A., & Mooney, S. E. (1989). Variable-ratio conditioning history produces high- and low-rate fixed-interval performance in rats. *Journal of the Experimental Analysis of Behavior*, 52, 167–179.
- Wearden, J. H., & Burgess, I. S. (1982). Matching since Baum (1979). *Journal of the Experimental Analysis of Behavior*, 38, 339–348.
- Weiner, H. (1969). Controlling human fixed-interval performance. *Journal of the Experimental Analysis of Behavior*, 12, 349–373.