CONCURRENT SCHEDULES AND MATCHING IN APPLIED SETTINGS: A REPLY TO FUQUA

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Given the obvious differences between laboratory and applied situations, it is natural to wonder whether the two settings are sufficiently similar to warrant extrapolations from one to the other (Fuqua, 1984). This is a question of the highest priority for basic research as well as for applied behavior analysis. In selecting furnishings for the operant chamber, an extremely austere style has traditionally been used. Basic researchers have deliberately simplified and standardized the situation so as to make functional relationships more readily apparent and to make results of different studies more directly comparable. If, as a consequence, there is not sufficient similarity between the operant chamber and the field situation to permit extrapolation from one to the other, then the operant chamber is in serious need of refurbishing.

We are, however, considerably more optimistic than Fuqua concerning the adequacy of the operant chamber as currently furnished. Most of the ways in which it differs from the applied situation should not affect the superiority of interval schedules, although these differences may produce deviations from matching. For example, differences in response topography, incompatibility, and changeover contingencies may produce undermatching and bias (Baum, 1974). Fortunately, the available evidence suggests that the superiority of interval schedules of reinforcement, and more specifically of variable-interval (VI) schedules, holds where bias or undermatching or both are observed (Myerson & Hale, 1984).

Our utilization of the matching law exemplifies a kind of applied mathematics that, although well established in other areas, e.g., operations research and systems analysis (Miser, 1980), may be unfamiliar to behavior analysts in both applied and basic research. In this approach, precision must often be sacrificed for mathematical tractability.

That is, situations may be idealized or simplifying assumptions made in order to expedite mathematical treatment. One such idealization is represented by our treatment of the relationship between response rate and reinforcement rate on VI schedules. For the present purposes, matching may also be considered as such an idealization. As we stated, "... the matching law provides a *useful approximation* of the relation between the distribution of reinforcements and the allocation of behavior" (Myerson & Hale, 1984, italics added). The assumption of matching allowed us to explore the interactions of different schedule types. If our assumptions had led to conclusions that only held when the assumed conditions were precisely true, then these conclusions would not be of interest to applied behavior analysts. However, because the conclusions are extremely robust and hold despite violations of the assumptions, we feel confident in presenting our suggestions here.

Although it may be true, as Fuqua suggests, that our conclusions could be reached via different routes, his argument for VI schedule superiority is strikingly similar to ours in a fundamental way. Although he focuses on the act of switching between schedule alternatives, both his approach and ours emphasize how the probability or rate of reinforcement changes as a function of behavior. Mathematical statements of the relationships between responding and reinforcements obtained on different schedules are termed *feedback functions* (Baum, 1973). And, in fact, as we indicated previously, our conclusions are not really about interval and ratio schedules, but rather are about procedures characterized by feedback functions similar to those of interval and ratio schedules.

To see how a feedback function analysis affects the evaluation of applied reinforcement procedures, consider time-sampling procedures in which

behavior is intermittently observed, and a response will be reinforced if it occurs during the observation period. Such procedures clearly make efficient use of the behavior analyst's time, as constant observation of an individual's behavior is not required (Axelrod, 1977). But do these kinds of procedures have the properties of interval or of ratio schedules? The answer to this question depends on what determines the duration of the observation period. (It is assumed that there are no stimuli signalling the beginning of an observation period; if there were, responding would, of course, quickly come under the control of such stimuli, and the procedure would not be very effective.) If the observation period continues until a response occurs and a reinforcer is delivered, then the procedure is both formally and functionally analogous to an interval schedule that 'sets up' an opportunity for reinforcement, which then remains available for an unlimited time. There will be no 'missed' opportunities, and reinforcement rate will be relatively insensitive to changes in response rate.

If the observation period is of limited duration, however, and terminates without reinforcement if no response occurs within the allotted interval, then the procedure is formally similar to a VI with a limited hold (Newby, Memmott, & Kendall, 1978). However, this procedure is functionally quite similar to a ratio schedule. The possibility of missed opportunities makes the rate of reinforcement extremely sensitive to the rate of response, the very property that characterizes the ratio feedback function. Therefore, the limited hold procedure suffers in comparison to the aforementioned unlimited hold procedure in exactly the same way that ratio schedules suffer in comparison to interval schedules. That is, the limited hold procedure would be ineffective unless it were richer than the schedule maintaining the inappropriate behavior.

Fuqua implies that the lack of applied research on VI schedules might reflect practical difficulties in implementing such procedures. For research purposes where precise VI programming may be required, there are alternatives to the obviously impractical use of a list of interreinforcement intervals and a stopwatch (for example, see Conger

& Killeen, 1974, for a practical procedure for implementing concurrent VI schedules in a social situation). On the other hand, the preceding discussion of intervallike feedback functions suggests that the power of the VI intervention is captured by *any* procedure in which an occasional, unpredictable, and unobtrusive observation period continues until one is able to 'catch 'em being good' and provide reinforcement. Such procedures are highly practical because the behavior analyst is free to engage in other activities (including observing and reinforcing the behavior of other clients) in the time between observation periods.

We have not attempted to reply to all the points raised by Fuqua. Instead, we have highlighted those issues whose treatment we felt would clarify our suggestions concerning the practical implications of the matching law. The generality and practicality of our suggestions are ultimately an empirical question, and proper skepticism is an appropriate beginning for empiricism. Such empirical evaluation will be on the right track so long as it is clear that (a) our suggestions concern the maintenance rather than the acquisition of appropriate behavior, (b) precise matching is not the issue, and (c) for practical purposes, careful imitation of laboratory practices is not necessary to obtain the benefits of intervallike interventions.

Dews (1963), in discussing the importance of reinforcement schedules, emphasized that he did not mean to imply that all behavioral phenomena could be reduced to schedule effects: "An influence can be all-prevailing without being all-embracing. No one would maintain that all mechanisms of physiology can be reduced to the laws of osmosis; yet osmotic phenomena are ubiquitous in physiology; wherever they can operate, they do; and the student of any physiological mechanism ignores osmosis at his peril" (p. 148). Similarly, Dews suggested that schedules of reinforcement are ubiquitous; wherever they can operate, they do; and that students of behavior cannot afford to ignore them. We would add that this applies especially to concurrent schedules of reinforcement as there may not be any situations, either in the laboratory or in the field, in which only one set of response-

reinforcer relations exists (Poppen, 1982). Therefore, with all due respect to Josh Billings, if what we know about concurrent schedules from basic research is not exactly so in applied settings, then we had better find out what is so, or our ignorance is our peril.

REFERENCES

- Axelrod, S. (1977). *Behavior modification for the classroom teacher*. New York: McGraw-Hill.
- Baum, W. M. (1973). The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior*, **20**, 137-153.
- Baum, W. M. (1974). On two kinds of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior*, **22**, 231-242.
- Conger, R., & Killeen, P. (1974). Use of concurrent operants in small group research. *Pacific Sociological Review*, **17**, 399-416.
- Dews, P. B. (1963). Behavioral effects of drugs. In S. M. Farber & R. H. L. Wilson (Eds.), *Conflict and creativity* (pp. 138-153). New York: McGraw-Hill.
- Fuqua, R. W. (1984). Comments on the applied relevance of the matching law. *Journal of Applied Behavior Analysis*, **17**, 383-388.
- Miser, H. J. (1980). Operations research and systems analysis. *Science*, **209**, 139-146.
- Myerson, J., & Hale, S. (1984). Practical implications of the matching law. *Journal of Applied Behavior Analysis*, **17**, 369-382.
- Newby, W., Memmott, J., & Kendall, S. B. (1978). Effects of a limited hold on changeovers maintained by concurrent interval schedules of reinforcement. *The Psychological Record*, **28**, 445-453.
- Poppen, R. (1982). The fixed-interval scallop in human affairs. *The Behavior Analyst*, **5**, 127-136.

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