COMMENTS ON THE APPLIED RELEVANCE OF THE MATCHING LAW

R. WAYNE FUQUA

WESTERN MICHIGAN UNIVERSITY

One of the goals of science is the construction of quantitative statements that accurately describe the covariation of two or more variables. The matching law (e.g., Herrnstein, 1961) is just such a quantitative statement; it describes a proportional relationship between the allocation of behavior on two concurrent response options and the distribution of reinforcement between the two concurrent behaviors. As with other scientific laws, efforts to assess and extend the generality of the matching law have taken two forms, empirical and conceptual. Systematic replications of the matching law have empirically validated its generality across a range of species, responses, and reinforcement parameters (see de Villiers, 1977 for a review). Others have induced a general behavioral theory from the accumulation of empirical data and offered interpretations and predictions that extend beyond the basic observations (e.g., McDowell, 1982). As interpretations of empirical data, such extrapolations are prone to certain inaccuracies. Occasionally, these extrapolations and the theories they represent prove blatantly false (e.g., Ptolemaic model of the solar system), but most (e.g., Newtonian physics) prove to be incomplete rather than incorrect and are eventually revised and refined (e.g., quantum mechanics) as evidence suggesting the limitations of existing theories accumulates. Never-

theless, extrapolations from existing data contribute to the progress of science by promoting and directing research; however, they should be undertaken with a healthy dose of scientific skepticism lest we take an inferential leap and find ourselves landing on something less than solid empirical ground. To paraphrase Josh Billings (a.k.a. Henry Wheeler) "It ain't what we know that gets us in trouble, it's what we know that ain't quite so."

In discussing the practical implications of the matching law, Myerson and Hale (1984) have extrapolated from laboratory research on the matching law to socially important human behaviors occurring in applied settings. Their efforts are laudable in that such conceptual interpretations may narrow the gap between basic and applied behavioral research that many have justifiably lamented (e.g., Deitz, 1978; Hayes, Rincover, & Solnick, 1980; Michael, 1980). Furthermore, they have proposed interpretations (e.g., the superiority of variable interval schedules over ratio schedules in competing for the allocation of behavior) and made quantitative predictions that could promote applied research on concurrent behaviors. Nevertheless, their suggestions are based on extrapolations from laboratory research primarily with nonhumans to humans behaving in applied settings and thus merit a skeptical evaluation. My purpose here is not to argue against speculative interpretations in general or about the veracity of specific interpretations by Myerson and Hale; the accuracy of their predictions and suggestions is ultimately an experimental issue. My purpose is to point out the limitations and pitfalls of their extrapolations (some of which the authors have noted in their article), to express some reservations about the relevance of a *quantitative* formulation of the matching law for applied behavior analysis, and to note some limitations on the applicability of their suggestions.

Preparation of this manuscript was supported in part by Grant #000917-15-0 from the Maternal and Child Health Services to the John F. Kennedy Institute and Johns Hopkins University School of Medicine where the author was a visiting fellow in the Division of Behavioral Psychology.

Thanks to Charles Catania, James Johnston, and Brian Iwata for their helpful comments on an earlier version of this article and to Jay Heckler for suggesting one of the examples used in this article.

Reprints may be obtained from R. Wayne Fuqua, Department of Psychology, Western Michigan University, Kalamazoo, Michigan 49008.

THE ANALOGY BETWEEN LABORATORY AND APPLIED CONCURRENT BEHAVIORS

The experimental analysis literature on concurrent behaviors is voluminous and suggests that the matching law has generality across a range of species, reinforcement schedules, reinforcers, and reinforcement parameters such as immediacy and magnitude of reinforcement (de Villiers, 1977). There is no doubt that concurrent schedules are ubiquitous in applied settings, but the relevance of laboratory research for human behavior in applied settings depends in part on the degree to which the applied and laboratory settings are functionally analogous. More specifically, are responses, stimuli, and functional relationships in the two settings sufficiently similar along critical dimensions to justify extrapolations between the two settings? As differences along critical dimensions increase, so does the tenuousness of the extrapolations.

One of the preconditions for obtaining matching is the scheduling of a changeover delay (COD) of some minimal duration to separate responses on one interval schedule from the delivery of reinforcers for responses on the alternative interval schedule (e.g., Brownstein & Pliskoff, 1968; Herrnstein, 1961). In the absence of CODs, concurrent superstitions are maintained by the adventitious reinforcement of switching between the response options (Catania, 1966). Seldom, if ever, are CODs between concurrent schedules explicitly programmed in applied settings, thus calling into question the relevance of the matching law to human behavior occurring in field settings. With a few notable exceptions (e.g., frequent activity changes with attention deficit disorder children), rapid or stereotypic alternation between response options does not seem to characterize human behavior, thus suggesting that other factors, perhaps "naturally occurring" CODs, may function to separate responding on the concurrent schedules. Empirically validating the existence of naturally occurring CODs would require the identification of a "switching" response and the delivery of a reinforcer for delimiting the COD. Unfortunately, it

is difficult to identify the reinforcer(s) maintaining behavior in applied settings because they are seldom the discrete, unconditioned reinforcers that are typically used in laboratory research on concurrent behaviors; thus support for naturally occurring CODs would be difficult to gather.

Another incongruity between laboratory and applied settings concerns the relation between the concurrent behaviors. Laboratory research has focused on responses that are incompatible—only one of the concurrent responses can be emitted at a given point in time. Although many concurrent behaviors in applied settings are of this nature, it is relatively easy to identify a number of topographically dissimilar concurrent behaviors that can be emitted simultaneously. For example, a person driving an automobile may engage in a complex set of driving behaviors while talking to a passenger, adjusting the radio, and eating. Casual observation suggests that interactions between such concurrent behaviors do occur, as exemplified by decrements in the concurrent behaviors when the stimulus conditions associated with reinforcement for effective driving suddenly change (e.g., emergency situations or adverse driving conditions). Nevertheless, procedures for delineating compatible from incompatible concurrent behaviors in applied settings have yet to be developed, the degree to which applied settings are characterized by compatible as opposed to incompatible concurrent responses is unknown, and the relevance of the matching law to such compatible concurrent behaviors is problematic.

Concurrent behaviors in applied settings may differ in yet another way from their analogues in laboratory settings. As Myerson and Hale acknowledge, the vast majority of laboratory studies have measured topographically similar concurrent behaviors, whereas most potential applications of the matching law involve topographically dissimilar responses. Published empirical validations of the matching law with topographically dissimilar responses are noticeably lacking and any attempts at such validation in applied settings will need to grapple with several quantification problems. How should response classes be equated across topo-

graphically different behaviors? Measures of time allocation (e.g., Baum & Rachlin, 1969; Brownstein & Pliskoff, 1968) between the topographically dissimilar behaviors would seem an ideal solution to this measurement problem but would require procedures to detect the onset and offset of each behavior under consideration. Topographically dissimilar responses may also differ in response complexity (e.g., multicomponent response chains of different length) and response effort. Such differences may be accommodated in the matching law by the addition of a bias factor, but could complicate both experimental validations of the matching law in applied settings and extrapolations regarding behavior management tactics.

In many applied settings it may be difficult to identify the reinforcers maintaining a given behavior because a seemingly small proportion of human behavior comes into direct contact with easily identified, primary reinforcers. Complicating matters further, the reinforcers maintaining a behavior may be multiple, they may be continuous (e.g., conversation, watching television) rather than discrete stimuli, and they may vary in quality or magnitude over time. Even simple reinforcement schedules may be difficult to identify accurately (e.g., Crossman, 1983). Schedules for which the reinforcing stimuli are socially mediated may vary across time as a function of changes in the reinforcing community (e.g., changing classmates) or other factors affecting the delivery of reinforcement by the reinforcing agents (e.g., becoming "satiated" with the disruptive but initially amusing antics of a classmate). Such problems with quantifying the reinforcement schedules would make it very difficult for practitioners to calculate the relative richness ratios, which are central to many of Myerson and Hale's predictions regarding response allocation, and further complicate systematic replications of the matching law in applied settings.

The applications suggested by Myerson and Hale involve adding an incompatible appropriate behavior to compete with a preexisting inappropriate behavior that, presumably, has an extensive reinforcement history. It is unclear what impact a dramatic difference in reinforcement history might have

on response allocation between concurrent behaviors, but such a situation would probably require some programming (e.g., instructions, response prompting) to ensure that the newly introduced concurrent behavior was emitted and that it contacted the arranged reinforcers.

Finally, the matching relationship appears to extend to situations where *more* than two concurrent behaviors are maintained by the same reinforcer (e.g., Pliskoff & Brown, 1976), suggesting that the effects of scheduling reinforcement for a concurrent behavior might extend beyond the response decreasing effects on the undesirable behavior to other behaviors maintained by similar reinforcers. In this fashion, even seemingly "benign" interventions such as the reinforcement of incompatible behaviors could produce undesirable "side effects" if desirable concurrent behaviors were inadvertently decreased.

Thus, it appears that a number of functional differences may exist between laboratory studies of concurrent behavior and concurrent responses occurring in applied settings. The above examples are not exhaustive and other potentially important differences (e.g., the amount of extraneous reinforcement in the environment) could be cited. The point here is not to argue that the matching law is irrelevant to human behaviors in applied settings. The generality of concurrent behavior research to applied behavior problems on a *qualitative* level appears to have face validity and at least a modicum of empirical support, as exemplified by research on differential-reinforcement-of-other-behavior (DRO) schedules (e.g., Poling & Ryan, 1982). Presently, however, laboratory concurrent behaviors are an imperfect analogue of those found in applied settings and extrapolation from the former to the latter should be made with caution.

THE ROLE OF MATHEMATICS

Myerson and Hale's suggestions are derived from algebraic transformations of the matching law. To their credit, the derivations are well described and easy to follow. Nevertheless, one must ask how

central is the math to the recommendations they suggest? On one level it should be acknowledged that the math is simply a tool for describing a theory of response allocation, and that practitioners need not acquire skill in such algebraic derivations to benefit from scheduling suggestions based on the matching law. The degree to which applied researchers interested in assessing the generality of the matching law will need to become familiar with mathematical formulations and derivations of the matching law is also questionable because the precision with which response classes are measured, reinforcers are quantified, and extraneous variables are controlled in applied setting does not approximate the degree of precision available in the laboratory. The level of control found in most applied settings is not commensurate with the level of precision afforded by mathematical formulations of the matching law. Attempts to assess the generality of the matching law in applied settings would be premature if such research was seriously hampered by technological problems in these settings and if such efforts detracted from applied research on concurrent behaviors of more immediate social significance.

Not only may the mathematics be premature for applied researchers, but matching law research and its associated algebraic formulations may be unnecessary for deriving the predictions suggested by Myerson and Hale. Their major prediction, the superiority of interventions based on variable interval schedules of reinforcement, could be derived from a molecular analysis of the reinforcement contingencies for switching between concurrent behaviors. When an appropriate behavior is reinforced on a variable interval schedule, the requirements for meeting the temporal contingencies of the interval schedule accrue even when behavior is allocated to the alternative schedule (i.e., when undesirable behavior occurs). Such is not the case with ratio schedules, where the accumulation of response numbers (not simply the passage of time) is required to meet the schedule contingency. Thus, the probability of reinforcement for switching to the desirable concurrent behavior increases with the passage of time when that behavior is reinforced

on an interval schedule. When the desirable concurrent behavior is reinforced on a ratio schedule, the probability of reinforcement for switching to the desirable behavior remains unchanged as long as behavior is allocated to the undesirable concurrent behavior. Thus, the different reinforcement probabilities for switching to the desirable behavior predict that variable interval schedules would "compete" for response allocation more effectively than ratio schedules. Note that this prediction corresponds with those based on the matching law without requiring mathematical computations of the type suggested by Myerson and Hale.

ARE THE IMPLICATIONS PRACTICAL?

Myerson and Hale have called our attention to one of perhaps many practical implications of the matching law (e.g., McDowell, 1982). The relative paucity of variable interval citations in the applied behavioral literature may exemplify the gap between basic and applied research, and Myerson and Hale's suggestions may narrow that gap by promoting applied research on variable interval schedules. Alternatively, the paucity of applied research on variable interval schedules may reflect some practical constraints on the application of such schedules. In most applied settings, variable interval schedules are more difficult to arrange than fixed interval schedules or ratio schedules. Furthermore, currently available treatment alternatives may further limit the applications suggested by Myerson and Hale.

For undesirable behaviors maintained by response consequences over which the practitioner has little control, extinction-based interventions may be precluded. Many of these undesirable behaviors can be effectively managed by programming response-contingent punishment for the undesirable behavior in accord with guidelines suggested by Azrin and Holz (1966), which include provisions for programming a desirable incompatible behavior that attains the same class of reinforcement as the undesirable behavior. In situations where punishment is inappropriate for practical or ethical reasons, the reinforcement of appropriate concurrent

behaviors is the intervention of choice, and suggestions regarding the reinforcement schedule for the concurrent behavior are most relevant. Applied researchers have taken advantage of this strategy; these interventions are referred to as differential-reinforcement-of-other-behavior (DRO) schedules (e.g., Poling & Ryan, 1982) and differential-reinforcement-of-incompatible-behavior (DRI) schedules. In most interventions, attempts are made to introduce the DRO or DRI schedules with reinforcement densities that are clearly more favorable than those for the undesirable behavior. If the incompatible (desirable) behavior can *initially* be reinforced under a schedule approximating continuous reinforcement, and if satiation is not a concern, then such a schedule would probably be preferred to variable interval reinforcement for the incompatible behavior. Eventually, the number of incompatible responses per reinforcer may be increased until a maintenance schedule for that behavior is empirically determined.

It is to this important but somewhat limited application, the maintenance of DRI interventions, that Myerson and Hale's comments are most directly relevant. As they suggest, variable interval reinforcement of a desirable incompatible behavior would probably maintain lower levels of undesirable behavior than ratio reinforcement of the incompatible behavior delivered at a similar response/reinforcer ratio. The relevance of their suggestions for DRO interventions is somewhat problematic because the completion of each interval of "not responding" has typically been reinforced on continuous rather than intermittent schedules such as a variable interval. Whether a DRO maintenance schedule based on variable interval reinforcement of brief intervals of not responding would prove more efficacious than continuous reinforcement of longer DRO intervals is an interesting empirical question. The same can be said about comparisons of DRO schedules requiring durations of not responding that vary from trial to trial with those in which the required interval of not responding remained constant.

In summary, Myerson and Hale's extrapolations from the matching law to the scheduling of rein-

forcement for concurrent behaviors are thought-provoking and should promote applied empirical research on the topic. Although future research may extend the generality of the matching law and prove their extrapolations accurate, the functional differences between concurrent behaviors in laboratory and applied settings are substantial and suggest that such extrapolations, if not premature, should be drawn with great caution. Although Myerson and Hale derived their predictions from algebraic manipulations of the matching law, similar qualitative predictions are derivable from a molecular analysis of the contingencies for switching between concurrent behaviors. Their quantitative predictions, although interesting, may prove difficult to validate because of limitations on experimental control and the accuracy of response and reinforcer quantification in applied settings. Finally, some limitations on the applicability of their suggestions are noted. In all fairness to Myerson and Hale, making inferential leaps beyond existing empirical data has a legitimate and important role in the accumulation of scientific knowledge. The same can be said about the inevitable response to such inferential leaps—conceptual and experimental work to delineate what we know from what ain't quite so.

REFERENCES

- Azrin, N. H., & Holz, W. H. (1966). Punishment. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 380–447). Englewood Cliffs, NJ: Prentice-Hall.
- Baum, W. M., & Rachlin, H. C. (1969). Choice as time allocation. *Journal of the Experimental Analysis of Behavior*, *12*, 861–874.
- Brownstein, A. J., & Pliskoff, S. S. (1968). Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, *11*, 683–688.
- Catania, A. C. (1966). Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 213–270). Englewood Cliffs, NJ: Prentice-Hall.
- Crossman, E. (1983). Las Vegas knows better. *The Behavior Analyst*, *6*, 109–110.
- Deitz, S. M. (1978). Current status of applied behavior analysis: Science versus technology. *American Psychologist*, *33*, 805–814.

- de Villiers, P. (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.
- Hayes, S. C., Rincover, A., & Solnick, J. V. (1980). The technical drift in applied behavior analysis. *Journal of Applied Behavior Analysis*, **13**, 275-284.
- Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, **4**, 267-272.
- McDowell, J. J. (1982). The importance of Herrnstein's mathematical statement of the law of effect for behavior therapy. *American Psychologist*, **37**, 771-779.
- Michael, J. L. (1980). Flight from behavior analysis. *The Behavior Analyst*, **3**, 1-21.
- Myerson, J., & Hale, S. (1984). Practical applications of the matching law. *Journal of Applied Behavior Analysis*, **17**, 367-380.
- Pliskoff, S. S., & Brown, T. G. (1976). Matching with a trio of concurrent variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, **25**, 69-73.
- Poling, A., & Ryan, C. (1982). Differential-reinforcement-of-other-behavior schedules. *Behavior Modification*, **6**, 3-21.

Received April 13, 1984

Final acceptance May 2, 1984