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On Terms

Resurgence

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Behavior that has not occurred for a period of time can, under some conditions, reappear. In a number of recent publications within behavior analysis, the term *resurgence* (occasionally *regression*) has been applied to situations in which behavior has recurred after a period of nonoccurrence (e.g., Dixon & Hayes, 1998; Mechner, Hyten, Field, & Madden, 1997; Morgan & Lee, 1996; Wilson & Hayes, 1996). Researchers investigating resurgence have used a wide range of procedures, including punishment (Wilson & Hayes, 1996), extinction (Dixon & Hayes, 1998; Morgan & Lee, 1996), and increased response requirements (Mechner et al., 1997), but all used the term *resurgence* to describe or explain the resulting behavior patterns. There has been little discussion about the use of this term to describe results from these very different procedures. The purpose of this paper is to consider different ways of defining *resurgence.*

RESURGENCE AS REOCCURRENCE AFTER A DELAY

Webster's dictionary defines *resurgence* as a rising again into life, activity, or prominence (Gove, 1993). Sometimes in behavior analysis, resurgence of a behavior has been used to mean just the reoccurrence of that behavior after a period of time since its last occurrence (e.g., Mechner et al., 1997). By this definition, there must be a period of time between the two occurrences; otherwise, there would be only one occurrence and not a reoccurrence.

Defining resurgence in this way, however, means that any delayed occurrence of the same topography after the first occurrence of a behavior could be termed resurgence. This would encompass almost all operant phenomena, because operant behavior involves the study of multiple occurrences of behavior over time. Exactly which reoccurrences should be termed resurgence would depend upon the period of time considered to be a delay. This raises the question of when is the delay long enough, to which there appears to be no sensible answer. Hence this definition of resurgence cannot separate resurgence from other operant phenomena and is therefore of little use. For the term to be useful, it must encompass phenomena that are not already described by other terms. Therefore, we will consider here the relation between resurgence and the conditions that occur during the delay.

EXTINCTION-INDUCED RESURGENCE

Epstein (1985) proposed a principle of "extinction-induced resurgence": "When, in a given situation, recently reinforced behavior is no longer reinforced, behaviors that were previously reinforced under similar circumstances tend to recur" (p. 144). The principle states both what extinction-induced resurgence is and the conditions under which it will tend to occur (see also

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Catania, 1992); *resurgence* is defined as the reoccurrence of a previously reinforced behavior (Behavior 1) under the condition that reinforcer delivery ceases for a more recently reinforced behavior (Behavior 2).

The cessation of reinforcer delivery for Behavior 2 is a necessary condition in order that the recurrence of Behavior 1 be termed extinction-induced resurgence. In addition, it is presumed that the occurrence of Behavior 1 has no other obvious sources of control. Epstein's definition therefore usefully limits the range of events that might be termed extinction-induced resurgence. The condition that controls resurgence for Epstein's principle of extinction-induced resurgence is the extinction of Behavior 2, with no other obvious changes in the contingencies that control Behavior 1. However, empirical studies focusing on extinction-induced resurgence alone have both found (e.g., Epstein, 1983) and failed to find (e.g., Cleland, Foster, & Temple, 2000) resurgence induced by the extinction of Behavior 2.

Although Epstein limits his discussions and research to resurgence in those situations involving extinction of Behavior 2, he mentions the possibility of reoccurrence of behavior in other situations, such as those involving punishment, satiation, or increased response requirements (Epstein, 1985). Epstein's definition of resurgence therefore does not preclude other types of resurgence from being defined by the conditions under which they occur, and in this way it is comparable to other definitions of resurgence. Keeping a broader operational definition of resurgence leaves open the possibility that extinction-induced resurgence is a subtype that occurs under conditions that can be experimentally determined.

RESURGENCE AS RECOVERY FROM REST: SPONTANEOUS RECOVERY

It has long been known that when the rate of a behavior has been reduced by extinction, a period of rest alone often results in a later rate increase; this has been termed *spontaneous recovery* (Kimble, 1961). In studies of resurgence, the period of time in which Behavior 2 occurs might be viewed as a period of rest for Behavior 1. If the rate of occurrence of Behavior 1 has been reduced by extinction prior to the extinction of Behavior 2, then any increase in Behavior 1 rate at the start of Behavior 2 extinction might be better termed spontaneous recovery (cf. Davis, Staddon, Machado, & Palmer, 1993). If, however, the rate of Behavior 1 has not been reduced by extinction prior to the cessation of reinforcer delivery for Behavior 2, then reoccurrence of Behavior 1 in extinction cannot be termed spontaneous recovery. Some definitions of resurgence (e.g., Epstein, 1985), however, would include the pattern of Behavior 1 in both cases.

This again points to the need for empirical consideration to clarify usages of the term *resurgence*. For example, if the extinction of Behavior 1 was found to be a necessary precondition for resurgence, and the degree of this resurgence was quantitatively the same as spontaneous recovery (i.e., without the training and extinction of Behavior 2), then the resurgence effect might be better subsumed within the phenomenon currently termed spontaneous recovery.

RESURGENCE AS RESPONSE VARIABILITY

For the term *resurgence* to be useful, it must describe phenomena that are not already encompassed by other terms or descriptions, and Epstein's (1985) definition limits resurgence to extinction procedures. A number of other studies, however, suggest that behavior becomes more variable when reinforcer delivery ceases (e.g., Antonitus, 1951; Eckerman & Lanson, 1969; Margulies, 1961; Millenson & Hurwitz, 1961; Millenson, Hurwitz, & Nixon, 1961; Morgan & Lee, 1996;

Notterman & Mintz, 1965; Stebbins & Lanson, 1962; Stokes, 1995). From this it might be argued that the changes in response probability here called resurgence are merely measured instances of behavioral variability induced by extinction within an impoverished environment.

Against this view of resurgence, Epstein (1983) compared the occurrence of a single, previously reinforced behavior with the occurrence of a behavior that had not been previously reinforced. This latter behavior served as a control for what might have occurred with Behavior 1 if, in fact, that behavior had not been reinforced. Epstein argued that because the previously reinforced behavior occurred more often during the extinction of Behavior 2 than the control behavior, its reoccurrence could not be considered solely the result of increased variability due to extinction. The topographies of Behavior 1 and of the control behavior were counterbalanced across subjects, and the results suggested that occurrence in extinction was not a function of operant rate of these two behaviors but rather depended on a prior history of reinforcement and extinction.

Demonstrating control over the *degree* of reoccurrence of Behavior 1 by manipulating historical variables (like the extent of extinction of Behavior 1), with reinforcer cessation of Behavior 2 kept constant, would also suggest that the reoccurrence was not due to variability in extinction. However, although Epstein (1983) did vary the amount of extinction of Behavior 1 across subjects, this was not done in a manner that enabled firm conclusions to be made.

RESURGENCE AS DEFERRED EXTINCTION

Control over the degree of resurgence of Behavior 1 has been investigated earlier, although these researchers did not use the term *resurgence* (Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson, & Mulick, 1975; Mulick, Leitenberg, & Rawson, 1976; Rawson & Leitenberg, 1973; Rawson, Leitenberg, Mulick, & Lefebvre, 1977). In one study for which there was no extinction of Behavior 1 prior to training Behavior 2, Leitenberg et al. found that during the training of Behavior 2, the occurrence of Behavior 1 was less frequent when Behavior 2 had been reinforced at a high rate than when Behavior 2 had been reinforced at a low rate. During the extinction of Behavior 2, however, the occurrence of Behavior 1 was greater when Behavior 2 had been reinforced at a high rate than when Behavior 2 had been reinforced at a low rate.

One hypothesis proposed by Leitenberg et al. (1975) to explain these results was that the reinforcement delivered for Behavior 2 prevented the extinction of Behavior 1. Procedurally, extinction conditions were in effect for Behavior 1 after its training, but these conditions may have made little contact with Behavior 1 given sufficient reinforcement for Behavior 2. In this view, the resurgence effect is observed because extinction of Behavior 1 has been deferred until after the extinction of Behavior 2 takes place. This gives rise to the empirical prediction that the degree of resurgence will be inversely proportional to the degree of prior extinction. Although Epstein (1983) argued that such an inverse relation might hold even of resurgence did not result from preventing the extinction of Behavior 1, how this might occur was not made clear.

RESURGENCE AS DESCRIBED BY THE MATCHING LAW

We have argued that current ideas about resurgence are descriptive of phenomena for which the conditions of control have not yet been fully explored. We would like next to consider a description of the so-called resurgence effect based on the matching law. Matching describes patterns of behavior and makes no pretense to "explain" what is observed further. In this way, it can help to clarify the different procedures said to produce resurgence, and to formalize the empirical testing still needed in this area. For simplicity we will assume that, as in Leitenberg et al. (1975), Behavior 1 is not exposed to extinction prior to training Behavior 2.

To begin this task, consider that the prevention of extinction view raises the question of how reinforcement for Behavior 2 could prevent or otherwise influence the occurrence of Behavior 1. During the training of Behavior 2, both behaviors are typically available concurrently. The matching law predicts that, all else being equal, the relative occurrence of two concurrently available behaviors will strictly match the relative rates of reinforcement available for those behaviors (Herrnstein, 1970). Even when all else is not equal, much data have still been usefully described by the generalized matching law:

$$\log\left(\frac{B_1}{B_2}\right) = a \log\left(\frac{r_1}{r_2}\right) + \log k, \quad (1)$$

where B_1 and B_2 are the rates of responding on the two alternatives, r_1 and r_2 are the obtained rates of reinforcement for each alternative, and a is the slope and $\log k$ is the intercept of the line relating the log behavior ratio to the log reinforcement ratio (Baum, 1974). This equation describes any linear relation between the logarithmic behavior and reinforcement ratios, with the two parameters, a and k, allowing description of the relative occurrence of two behaviors that do not strictly match the relative rates of reinforcement obtained.

Matching is an aggregated phenomenon requiring a population of behavior and reinforcement events. It is typically demonstrated with relative rates of reinforcement kept constant until the relative rates of behavior are deemed stable. This is referred to as steady-state behavior (Sidman, 1960). In the study of resurgence, on the other hand, the point at which reinforcement for Behavior 2 begins is often the same point at which reinforcement for Behavior 1 ceases. Behavior that occurs when relative rates of reinforcement or other variables are changed is referred to as transition behavior (Sidman, 1960). There are a few different models (cf. Davis et al., 1993) that can deal with transitions, but we will illustrate with a common matching model.

Davison and Hunter (1979) proposed that the distribution of behavior over two concurrent schedules during the transition from one relative reinforcement rate to another was a joint function of the current reinforcement ratio and the past reinforcement ratios. Behavior allocation in session n is a function of the reinforcement ratios in session n, session $n - 1$, $n - 2$, and so forth, as shown below with the free parameters used in Equation 1.

$$\log\left(\frac{B_{1(n)}}{B_{2(n)}}\right) = a \log\left(\frac{r_{1(n)}}{r_{2(n)}}\right) \cdot b \log\left(\frac{r_{1(n-1)}}{r_{2(n-1)}}\right) \times c \log\left(\frac{r_{1(n-2)}}{r_{2(n-2)}}\right) \cdots + \log k. \quad (2)$$

Davison and Hunter noted that this model could not account for schedule changes involving extinction because the reinforcement ratios would approach infinity. They proposed instead that the behavior ratio from the last session ($n - 1$) could be used to summarize the effect of the past reinforcer ratios, because this behavior ratio would be less likely to approach infinity.

In the Leitenberg et al. (1975) study, however, only one behavior was reinforced at a time and the transition was between two simple schedules. Thus, there were no reinforcer ratios or behavior ratios for behavior in transition, so the model proposed by Davison and Hunter (1979) does not strictly apply. It is likely, however, that the allocation of behavior in the transition between simple schedules is a function of past and current reinforcer rates, as suggested for concurrent schedules by Davison and Hunter (1979). If so, then the occurrence of Behavior 1 during the training of Behavior 2 should be a function of the ratio of the past rate of reinforcement for Behavior 1 and the current rate of reinforcement for Behavior 2.

In this way we can derive two assumptions that help to describe some of the resurgence phenomena in terms of the matching law: first, from Davison and Hunter (1979), the assumption that the occurrence of Behavior 1 during the reinforcement of Behavior 2 is a function of both the past rate of reinforcement of Behavior 1 and the current rate of reinforcement of Behavior 2; and second, from Leitenberg et al. (1975), the assumption that the occurrence of Behavior 1 during the extinction of Behavior 2 is an inverse function of the degree of occurrence of Behavior 1 during the training of Behavior 2. If these two assumptions are correct, then the ratio of the occurrence of Behavior 1 during Behavior 2 training to the occurrence of Behavior 1 during Behavior 2 extinction (resurgence) should match the ratio of the obtained reinforcer rate for Behavior 1 to the obtained reinforcer rate for Behavior 2. That is,

$$\log\left(\frac{B_{1t}}{B_{1e}}\right) = a \log\left(\frac{r_1}{r_2}\right) + \log k, \quad (3)$$

where B_{1t} refers to the occurrence of Behavior 1 during the training of Behavior 2, B_{1e} refers to the occurrence of Behavior 1 during the extinction of Behavior 2, r_1 is the rate of reinforcement of Behavior 1 when it was reinforced, r_2 is the rate of reinforcement for Behavior 2 when it was reinforced, and the parameters a and k are those of Equation 1. This equation essentially assumes that the total occurrence of Behavior 1 in extinction is distributed between B_{1t} and B_{1e} in proportion to the relative reinforcer rates for B_1 and B_2 training periods. More Behavior 1 will occur in Behavior 2 training if r_1 is high relative to r_2, and vice versa.

These variations of the generalized matching law are consistent with the phenomenon of resurgence, although no direct tests have been made in the context of the resurgence literature. If such models turn out to be supported by data, then the phenomena now termed *resurgence* can be described by a variation of the generalized matching law.

CONCLUSIONS

There are many conditions in which an earlier behavior is observed to increase when "something happens" to one or more otherwise-unrelated behaviors. Labeling any one particular set of conditions exclusively as *resurgence* seems premature, given the possibility that such conditions may prove to be subsumed under some general principles in the future. We have illustrated one way, using the generalized matching law, of providing a description of the more general conditions in which an earlier behavior appears or disappears contingent upon a second event that is otherwise unrelated, although this does not cover other possible cases of resurgence from rest and satiation. It also seems premature to develop a catalogue of subtypes without better empirical data. The occurrence of a previously reinforced behavior when reinforcer delivery ceases for a recently reinforced behavior has been the most commonly studied scenario, but it is not the only one. Finally, the use of other terms in this literature, such as *induced, recovery, spontaneous recovery,* and *regression,* do not add further explanation to what we know and are theoretical embellishments that easily lead us astray.

Although the term *resurgence* is sometimes used as an explanation, like all terms it is descriptive rather than explanatory. When used descriptively, the term is perhaps harmless in many instances. We need to be wary, though, of being misled into thinking that all uses of the term refer to the same phenomena or contexts. That is the problem that prompted this review. We argue that the term can be dropped without loss when discussing the details of specific procedures and the behaviors produced. We hope that, like the terms *preference* and *motivation, resurgence* will come to be replaced by clearer procedural definitions of the situations that commonly give rise to these observations.

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