

Variability as an Operant?

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A series of experiments on operant variability by Neuringer and colleagues (e.g., Neuringer, 1986, 2002; Page & Neuringer, 1985) have been repeatedly cited as showing that behavioral variability can be reinforced by making reinforcement contingent on it (e.g., Catania, 2007; Neuringer, 2009; Neuringer & Jensen, 2012; Pierce & Cheney, 2004). For instance, Page and Neuringer (1985) made reinforcement contingent on a sequence of a fixed number of key pecks by a pigeon whenever the sequence differed from the previous n sequences in a lag n contingency. They showed that the degree of variability in pigeons' eight-peck sequences, as measured by U values, increased with an increasing lag requirement. As a result, Page and Neuringer concluded that variability is an operant.

The argument that variability should be considered to be an operant dimension of behavior, just like other reinforcement properties, such as topography, frequency, duration, force, and location (e.g., Neuringer, 1993, 2009; Neuringer, Deiss, & Olson, 2000; Page & Neuringer, 1985) is based on two premises. First, there has to be a correspondence between reinforcement contingencies that require behavioral variability and the actual variability of behavior. Second, alternative explanations of that variability need to be ruled out.

As Barba (2012) points out, many studies by Neuringer and others have shown that reinforcement contingencies

can be arranged to produce behavioral variability. Yet, referring to Catania's (1973) treatment of the concept of the operant, Barba questions whether the existing evidence supports the notion of "variability as an operant" (e.g., Page & Neuringer, 1985). In the operant-class terminology suggested by Catania (1973), a descriptive class specifies the criteria on which reinforcement is contingent, a functional class specifies the class of responses generated by that contingency, and the concept of the operant is appropriate to the extent that there is a correspondence between the descriptive and the functional classes. Reviewing the literature on variability as an operant, Barba shows that the functional class (the measure of variability; U values), does not match the descriptive class, consisting of responses that differ from n previous instances in a lag n contingency (or responses that have occurred with relatively low frequencies recently in frequency or threshold procedures). Hence, the required correspondence between descriptive and functional classes has not been shown, and variability as an operant has not thus far been demonstrated. Barba suggests that the problem can be resolved simply by using cumulative U values as the reinforcement criterion, and that such an arrangement could provide more convincing evidence in favor of the notion of variability as an operant. Hence, the issue of correspondence between reinforcement contingencies that require behavioral variability and the actual variability of behavior may be resolvable.

Another way to achieve that correspondence between descriptive and functional classes would be, simply, to stick to percentage of reinforced

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trials as the dependent variable, that is, as the functional class. That class, however, is not the “operant variability” class that Neuringer has focused on.

Quasirandom Versus Memory-Based Variability

Neuringer and colleagues (e.g., Neuringer, 2002; Neuringer & Jensen, 2012; Page & Neuringer, 1985) have distinguished between memory-based and quasirandom variability. In more colloquial terms, memory-based variability consists of doing things that one has not done recently. On the other hand, quasirandom variability consists of doing, approximately equally frequently, a number of different things. Machado (1993) has shown both of these patterns in pigeons. When reinforcement was contingent on relatively simple response sequences with a low lag criterion, the birds effectively cycled between the sequences that satisfied the lag contingency. However, when the required sequences were more complex, the birds engaged in more “random-like behavior” that was not discriminatively controlled by prior sequences.

The so-called memory-based variability can easily become quite repetitive, as when in a Lag 2 contingency, pigeons cycle through three different responses or response sequences and thereby satisfy the reinforcement requirement on every trial (e.g., Machado, 1993). Hence, the operant variability that is the main focus of Neuringer and colleagues is the quasirandom variability: “variability is an operant—it can be reinforced—and ... a stochastic generating process may be responsible” (Neuringer & Jensen, 2012, p. 73).

What Is Reinforced?

Even if the issue of correspondence between descriptive and functional classes may be resolvable, the issue of alternative explanations of the observed variability may not be as easily

resolved. First, there is the question of what is being reinforced or, even, what is reinforceable. As Skinner (1969) pointed out, “the topography of an operant need not be completely fixed, but some defining property must be available to identify instances. An emphasis upon the occurrence of a repeatable unit distinguishes an experimental analysis of behavior from historical or anecdotal accounts” (p. 175). The repeatable and identifiable unit in experiments on operant variability typically consists of a fixed number of pecks or presses distributed on two operanda. In the typical variability experiment (e.g., Page & Neuringer, 1985), the completion of eight pecks led to either reinforcement or a time-out. Thus, there was a forced break after eight pecks, and the functional unity of an eight-peck sequence was not otherwise established.

Experiments have clearly indicated that the response sequences typically required in operant variability studies are not directly reinforceable. When contingencies reach a certain degree of complexity, optimal patterns of responding simply do not develop. For example, so-called memory-based responding breaks down in pigeons when, using a frequency-dependent variability contingency, the required response sequences consist of more than two left or right pecks (e.g., Machado, 1993). Other experiments have shown that when reinforcement is strictly contingent on more complex response sequences on a left (L) and a right (R) lever, such as RLLRL or LLRRL, rats do not learn to emit the target sequence. Unless additional reinforcers were contingent on variable response sequences, responding stopped when reinforcement was strictly contingent on a specific extended response sequence that included one or more changeovers between operanda (Neuringer et al., 2000). Variability is not a characteristic of a single response, but of a response only in

the context of prior responses. If the response sequences that are followed by reinforcement are not directly reinforceable, the direct reinforcement of variability of those sequences seems even less likely.

The complexity of the contingencies makes it difficult to see the detailed effects of reinforcement. Perhaps a lag contingency arrangement that requires responses to different operanda, instead of different, complex sequences on just two operanda, would make it easier to study the effects of reinforcement.

In one such recently completed experiment in our lab, we reinforced four different responses in rats according to a Lag 3 contingency. Four rats participated in daily 30-min sessions run in Campden rodent test cages. In addition to two standard levers, we constructed and mounted a wood lever and a photocell operandum. Pressing either the left lever, the right lever, or the wood lever, or poking the nose into the photo-cell operandum, produced water if, and only if, all other three response types had occurred since the last occurrence of that particular response type. Under this contingency, a consistent pattern of cycling through the different response types developed, with almost every response producing a reinforcer, as can be seen in the cumulative record from the first 8 min of Session 56 (Figure 1, top).

Next, in Session 57, we introduced a fifth operandum, a chain from the ceiling, and changed to a Lag 4 contingency. In Figure 1 (center), the cumulative record shows that the rat pulled the chain almost immediately, and the response produced the reinforcer (as indicated by the vertical mark at A). The immediate effect of that single reinforcement following a new response was clearly not more variability (or novelty), but several repetitions of that particular response (i.e., chain pulling) that had been followed by the reinforcer. Chain pulling was then extinguished

until all other four response types had occurred, and the cumulative record shows a decelerating response rate exactly as expected during extinction (B). After all the other four response types had occurred, chain pulling was again reinforced, and a new burst of responses occurred during a second extinction period, and so on, with all response types cycling between reinforcement and extinction.

Finally, 16 sessions later (Session 73, bottom panel), chain pulling was nicely intermingled with the other four response types, but the percentage of reinforced responses was clearly lower than in Session 56, when only four different responses were required. Thus, after the change from four to five response types, the rat's response variability changed from "memory based" to more quasirandom.

Some Well-Established Empirical Findings

There is a consistent finding that contingencies that permit variability but do not require it produce repetitive response topographies (e.g., Iversen, 2002; Page & Neuringer, 1985). On the other hand, extinction produces variability. Of course, consistent and extended extinction may not produce much behavior, but when extinction alternates with reinforcement, it is typically during extinction that variable, or even novel (cf. Holth, 2012; Pryor, Haag, & O'Reilly, 1969), behavior emerges. A very clear demonstration was provided by Iversen (2002) who arranged for rats to automatically take snapshots of themselves every time they operated an omnidirectional pole during continuous reinforcement and during extinction. As evident from that experiment, rats showed a remarkable variability in response forms very quickly during extinction, after having displayed astonishingly fixed response topographies during reinforcement.

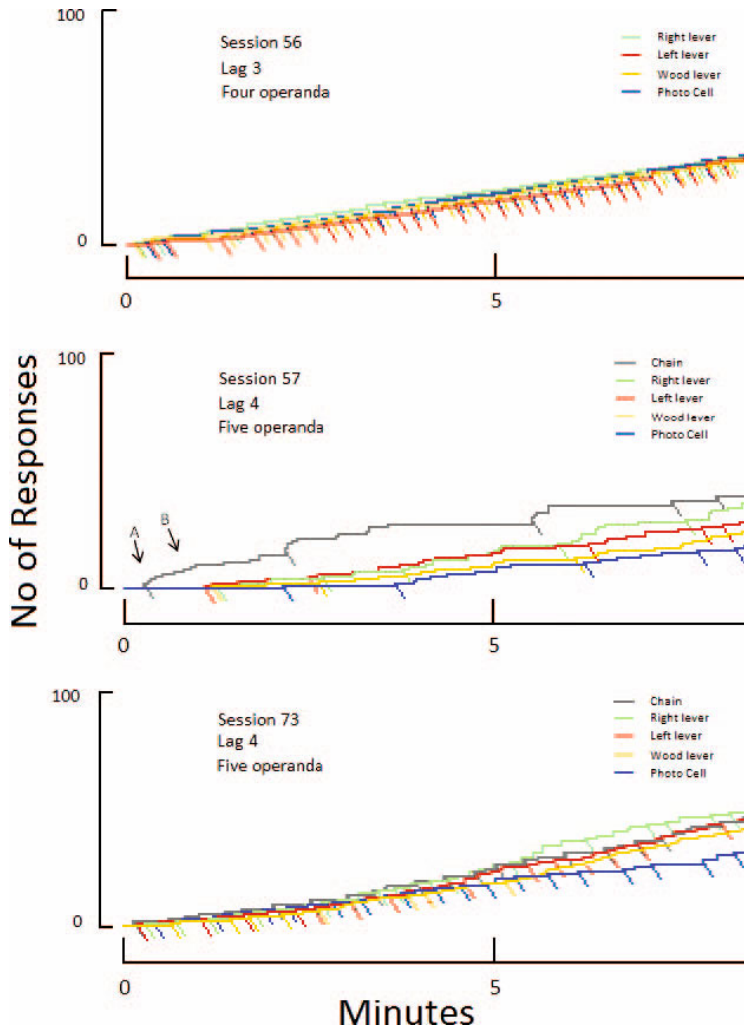


Figure 1. Each panel shows cumulative records of different response types during the first 8 min of a 30-min session. The top panel shows four different response types during a Lag 3 contingency. The middle panel shows responding when one new operandum is added to the previous four operanda, the lag is set to 5, and the new response is reinforced (A) and extinguished (B). The bottom panel shows all five different response types intermingled relatively randomly after several sessions with the Lag 4 contingency in operation.

A second well-established and potentially relevant finding is that the extinction process gradually speeds up as a result of repeated extinction (e.g., Clark & Taylor, 1960; Perkins & Cacioppo, 1950). Inherent in the reinforced novelty and reinforced variability procedures is the repeated differential extinction of recently emitted behavior.

Third, a reinforcer can obtain the effect of an S^{Δ} for continued responding, such as is typically the case

immediately following reinforcement on a fixed-interval schedule (Ferster & Skinner, 1957). In fact, all procedures used in experiments referred to by Neuringer and colleagues as showing that variability is an operant dimension of behavior have the differential extinction of repetitive behavior as a common variable. Whereas the lag n procedures differentially extinguish responses that are among the n most recently occurring response types, the frequency or threshold procedures

differentially extinguish responses that have recently occurred with relatively high frequencies, and statistical evaluation procedures differentially extinguish responses or sequences that are predicted by specific statistical analyses (Neuringer & Jensen, 2012).

An Alternative to Variability As an Operant

So, what constitute reinforceable behavioral units, and how much of the operant variability is explainable in terms of well-known basic principles, without the additional assumption that variability itself must be considered as a reinforceable property of behavior? We do know that pecking different keys as well as changeover between keys can be reinforced in pigeons, and Machado (1997) showed that variation of eight-peck sequences in pigeons can be increased by differential reinforcement contingent on a number of changeovers between keys rather than on sequence variability itself.

Based on the report by Page and Neuringer (1985), as well as other reports of experiments in which operant or quasirandom behavioral variability has been demonstrated, three characteristics of the procedures seem evident: (a) Reinforcement is contingent on sequences that may be too complex to be directly reinforceable, yet (b) reinforcement will follow a diversity of different responses that are directly reinforceable, frequently enough to maintain responding, even though (c) repetitive responses (or sequences) are extinguished. An alternative interpretation of what Neuringer and colleagues designated as operant variability is that it may arise from a mix of many reinforced responses, such as key pecks and changeovers, cycling in and out of extinction according to patterns that are “chaotic” or quasirandom in the sense that they are sufficiently complex for

the discriminative control exerted by prior sequences to break down.

Memory-Based Variability in Human Affairs

Even if the variability demonstrated in many animal experiments has been shown to be more quasirandom than memory based, memory-based variability must play an important role in many human affairs. Very early, children learn not to repeat the same utterances in normal conversations. The result of a contingency in which the same response is never reinforced twice within certain time limits could, perhaps, fit the description of zero-trial extinction. An illustrative human example is what happens when small children learn to tell a joke and experience reactions from an audience. As every parent can testify, the immediate result is that telling the joke is repeated. Reinforcement for repeatedly telling the same joke will, however, quickly fail to appear. Soon, the child will learn not to repeat a successful joke (at least to the same audience) but may be likely to tell another one. On the other hand, a more quasirandom verbal behavior may develop when discrimination of one’s own previous behavior breaks down, such as in patients with Alzheimer’s disease.

Conclusion

There is abundant empirical evidence that shows that behavioral variability increases when reinforcement is contingent on it (e.g., Neuringer, Kornell, & Olufs, 2001; Page & Neuringer, 1985; Ross & Neuringer, 2002). Identifying the sources of behavioral variability and novelty is important in behavior analysis, and Neuringer and colleagues are to be commended for their thorough investigation of contingencies that produce predictable levels of behavioral variability. So, does it matter whether we talk about “variability as an operant” or about the cyclic

reinforcement and extinction of many responses? At worst, the notion of variability as an operant on its own is misleading to the extent that it suggests that the “reinforced variability” transcends the range of specific responses that are followed by reinforcement. In fact, as summarized by Neuringer and Jensen (2012), varying is “generally limited to the reinforced set” (p. 000). At best, the notion of variability as an operant on its own seems superfluous, because the variability seen in the relevant experiments seem to be properly accounted for in terms of well-known basic principles. Moreover, no special random or stochastic generating processes seem necessary, because the complexity of certain reinforcement contingencies in which several responses reciprocally cycle between reinforcement and extinction seems sufficient to explain the resulting quasirandom performances.

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