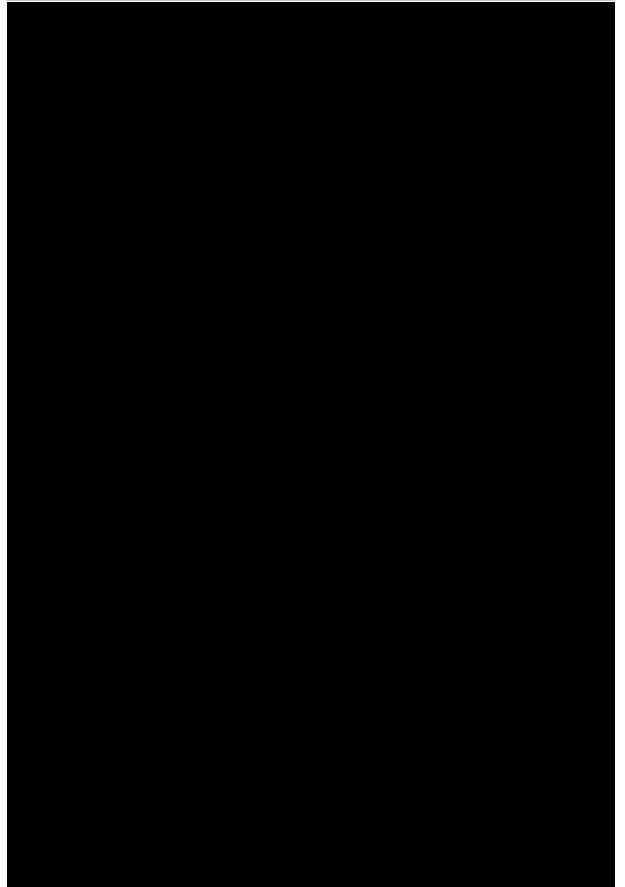


Behaving in an unusual, variable, or unpredictable manner is sometimes functional. An individual may sample new paths to reach a goal, invoke varied strategies when competing with an

has two possible states, heads up and tails up. Novel responses are those that have not prev

at the short end and large at the long end, and increased systematically across the IRT range. For the response to be reinforced, a pigeon's IRT had to fall in the bin that contained the fewest prior entries, across a moving window of 150 responses. Fine-grained analyses of the pi-



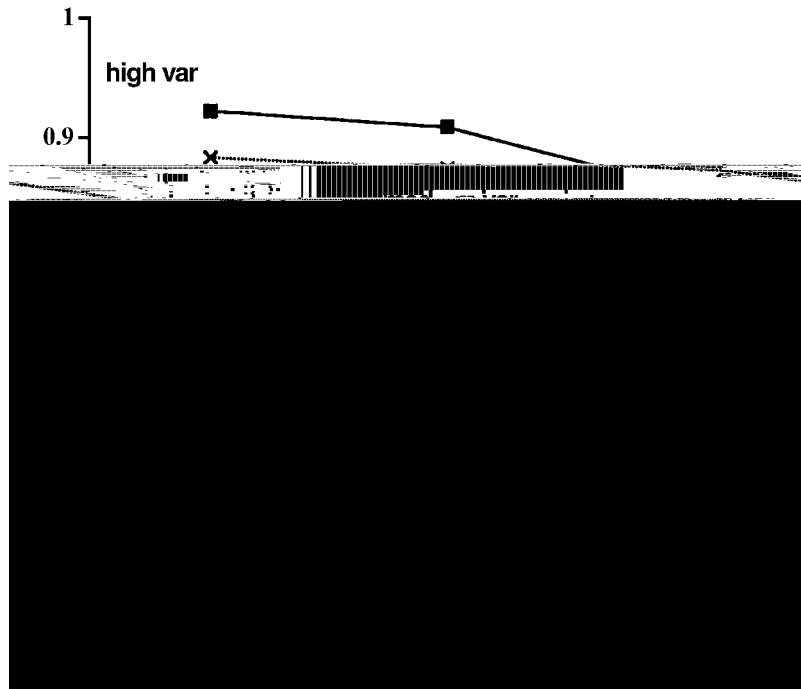
and, therefore, the random simulation often failed to meet the 4L + 4R constraint. The implication was that if the birds attempted to respond randomly, they would be reinforced only rarely.

To test whether the penalty for fifth pecks was responsible for the birds' failure to vary, Page and Neuringer (1985) permitted eight responses across L and R keys without the four responses-per-key requirement. If the current sequence of eight responses differed from that in the last trial, a lag 1 variability contingency (without constraint), reinforcement was provided. Now the pigeons succeeded in varying, attaining reinforcement on more than 90% of the trials, a rate significantly higher than that observed in Schwartz (1982) and close to that of the simulating random responder under the new procedure. Page and Neuringer also replicated Schwartz's (1982) variability + constraint procedure, and again the pigeons failed, just as did Schwartz's. The evidence was clear: Under Schwartz's (1982) procedure, pigeons failed to vary, but penalty for fifth responses was responsible.

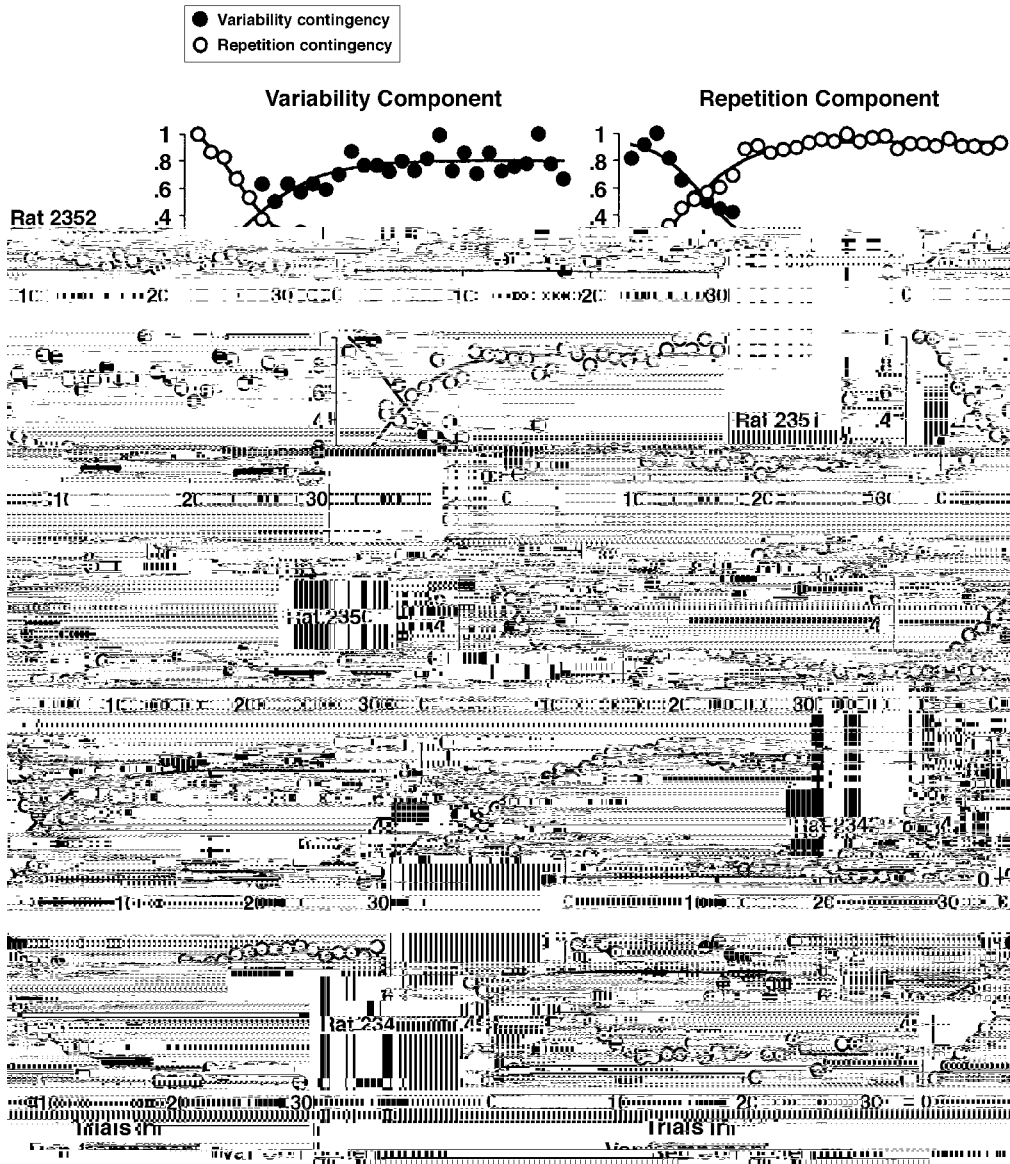
One additional aspect of Schwartz's

Some studies report that variability increases when reinforcement frequencies decrease (Boren, Moerschbaeher, & Whyte, 1978; Tatham, Wanchisen, & Hineline, 1993; Tremont, 1984), but others report small or no effects (Blough, 1966; Eckerman & Lanson, 1969; Herrnstein, 1961; Machado, 1989).

Grunow and Neuringer (2002, Experiment 1) independently manipulated variability contingencies and reinforcement frequencies, and their results may help to explain the previous inconsistencies. Four groups of rats were studied, with the contingencies for each group requiring a different minimum level of variability. (A threshold contingency was employed, the details of which will be described below.) In the initial phase, reinforcement was provided whenever the respective contingencies were met (reinforcement frequency was relatively high in this phase) and, as can be expected from the Blough (1966) and Machado (1989) studies described above, levels of variability were directly controlled by the contingencies. In



crease somewhat. Importantly, the artist would continue to behave much more variably than the assembly-line worker. Both contingency and frequency affect response variability, but contingency appears to be more influential, at least over the range of values studied to date. These findings, if general, are important for those who withhold



of required variability. It may also be maintained much longer because, as will be seen shortly, extinction weakens responding.

Choice

The frequency of one response relative to others, or response probability, is used as a measure of choice or preference. Choices are found to match the

rent sequence repeated at least one of the previous three. On an average of once every 30 sec (VI 30 sec), the computer probabilistically primed reinforcement for Var or Rep, the prime being maintained until the reinforcement had been collected. Thus, if the computer primed Var, reinforcement was delivered whenever the lag 3 variability contingency was next met. Similarly, if Rep had been primed, the next Rep sequence was reinforced. Probabilities of Var and Rep reinforcements were systematically manipulated, the two always summing to 1.0, and a matching-type relationship was obtained (Figure 4, panel A). The relationship was more complex than simple matching, possibly because, if the pigeons chose to vary by responding stochastically, there was some probability, due to chance, that the current sequence would repeat a previous sequence. This was shown by a comparison of pigeon performances to the performance of a computer-simulated stochastic model programmed to match its Var choices to the probability of Var reinforcements: The pigeons' choice distributions were found to be the same as the model's (Figure 4, panel B). Thus, choices to vary or repeat were governed by relative frequencies of reinforcement. An animal can choose whether, when, and how much to vary, a result consistent with those described above from Blough (1966), Machado (1989), and Grunow and Neuringer (2002). Choices of whether or not to vary appear to be governed similarly to all other operant choices.

These findings may have important applications. When an individual repeatedly responds in a way that is nonfunctional, reinforcement of choices to vary may help the individual to emerge from the ineffective pattern. This can be true for those experiencing everyday problems but feeling helpless to change, and it may be especially important for those experiencing depression or who respond in otherwise abnormally stereotyped manners, such as those with autism. These topics will be considered in a later section.

Extinction

As was indicated above, extinction is often found to increase variability, but almost all studies of this effect involve responses that had previously been repetitive. Antonitis (1951), for example, reinforced rats for poking their noses anywhere along a 50-cm horizontal opening. Although the exact location of pokes did not matter, with continued training, responses became limited to one or a few locations along the strip. When reinforcement was withheld, variability of location increased (see also Eckerman & Lanson, 1969). Variability produced by extinction has been reported for many other response dimensions as well, including force (Notterman & Mintz, 1965), number (Mechner, 1958), topography (Stokes, 1995), and sequence (Balsam, Paterniti, Zechow, & Stokes, 2002; Mechner, Hyten, Field, & Madden, 1997).

The issue is complicated, however, by other studies that show that previously reinforced responses and response patterns are maintained intact during and after extinction. That is, extinction does not break down

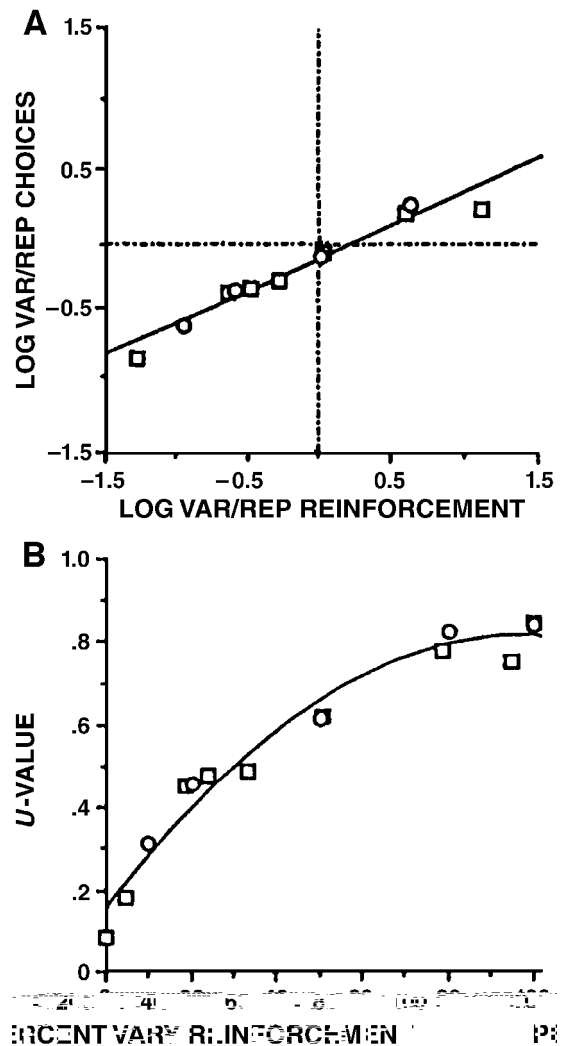


Figure 4. Average performance across a group of pigeons in Neuringer's (1992) study of choices to vary or repeat. (A) Logarithms of the ratio of number of times the pigeons met the Var contingency divided by the times they met the Repe-30 (im) -9730 () -30

learned patterns. For example, when Schwartz (1981) reinforced pigeons for any sequence of four L and four R responses, each bird developed a dominant sequence, as described above, and these sequences were maintained during extinction. Despite decreasing response rates during extinction, response patterns were retained. Similar maintenance of response structure has been observed during extinction following reinforcement of

choices (Myerson & Hale, 1988), responding under
(h) -48

the variability contingency four times, FR 4. The results were that, as the food reinforcer was approached (i.e., as progress was made through the ratio), the subjects were less and less successful at varying. The probability of meeting the variability contingency in the first trial after reinforcement was higher than it was in the second, which in turn was higher than that in the third trial, and so on. For comparison, a Rep group was reinforced for repeating sequences, once again with reinforcement only after four successful repetitions. Probability of repeating increased with proximity to reinforcement, a finding consistent with the literature but opposite that for the variability group. Thus, approach to reinforcement facilitated operant repetition but interfered with operant variability. Similar variability-interfering effects have been documented for within-trials responses: The probability that a response repeats the just prior response increases within a trial, even when sequence variability is reinforced (McElroy & Neuringer, 1990; Neuringer, 1991). To return to the example of a composer rushing to complete her composition, she may indeed

number of occurrences of each of the 16 possible sequences LLLL, LLLR, LLRL, and so on. If the relative frequency of the current sequence—the number of its occurrences divided by the sum of all 16 sequences—was below a

in one study lowest baseline variability was observed when rats pulled trapezes, intermediate levels were observed when they pushed keys, and highest levels were observed when they pressed levers (Morgan & Neuringer, 1990), with variability increasing in all cases when it was reinforced. In

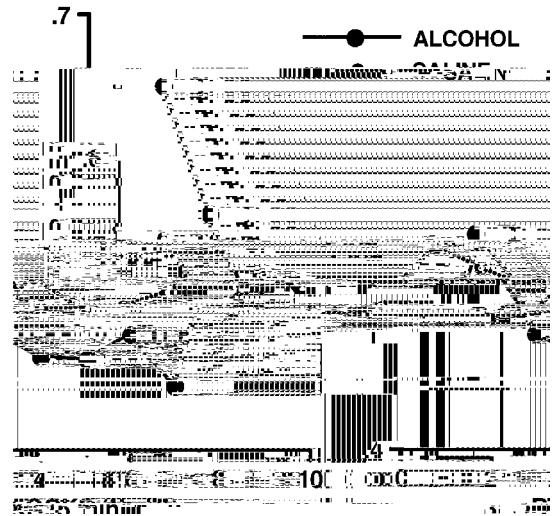
the right-only condition, a human observer had to decide whether a response had occurred and then present the reinforcer, necessarily leading to longer and more varied latencies and a less consistent contingency. Furthermore, there are many cases in which increasing constraints, such as those due to a decrease in the number of responses per trial

two for intermediate levels. In other ways, the procedure was similar to that of the Neuringer, Deiss, and Olson (2000) RVS contingencies just described, with a single, difficult target sequence always reinforced. The results were that the higher the level of reinforced baseline variability, the more quickly

the stereotyped behaviors preferred by the child, the result was increased social interactions, both during the period of the experimental manipulation and in 1- and 2-month follow-ups. These three studies, taken together, suggest that reinforcement of varied behaviors may facilitate modification of nonfunctional ritualistic and stereotyped behaviors.

Depression. Depression provides another example of maladaptive consequences of low variability. Lapp,

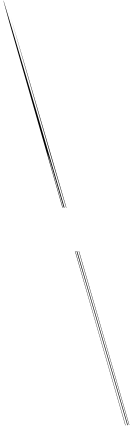
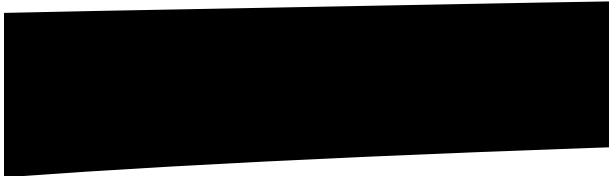
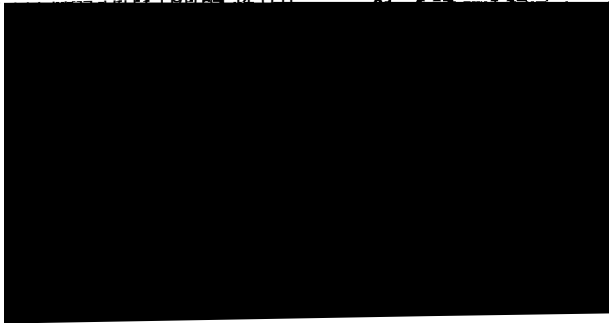
(1990) with a multiple schedule in which each rat served as its own control. In the same animals and within the same sessions, alcohol degraded Rep performances but left Var intact. Thus, alcohol appears to interfere with a task that requires working memory, as presumably is the case for the Rep task, but not with

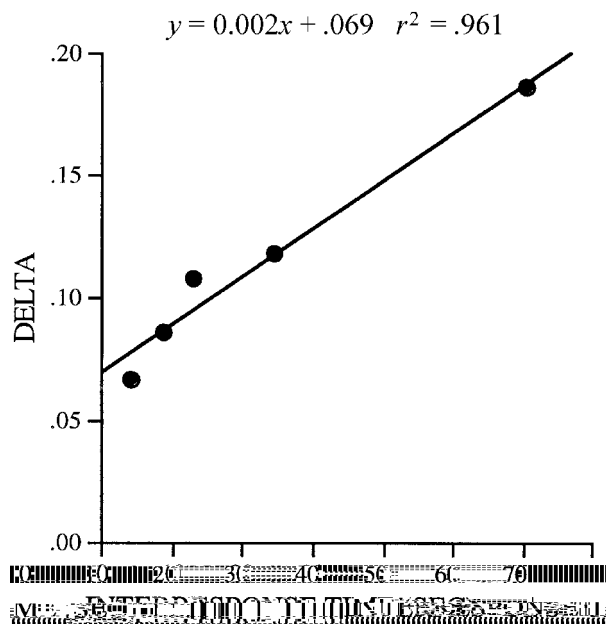


Noncontingent events. Noncontingent events, sometimes referred to as chance, accidents, or luck, also affect behavior. One happens upon a particular passage in a book that leads to a new thought; one happens to sit next to an interesting woman or man on an airplane, which leads to marriage (Bandura, 1982). In science as well as in everyday life, accidents, or serendipity, are an important part of the process of discovery (Beveridge, 1957). In each of the cases presented above, an accidental event leads to new behaviors that are then strengthened by consequences. The same is potentially true for variability itself. Particular levels of variability might occur for adventitious reasons, but then become functionally related to consequences.

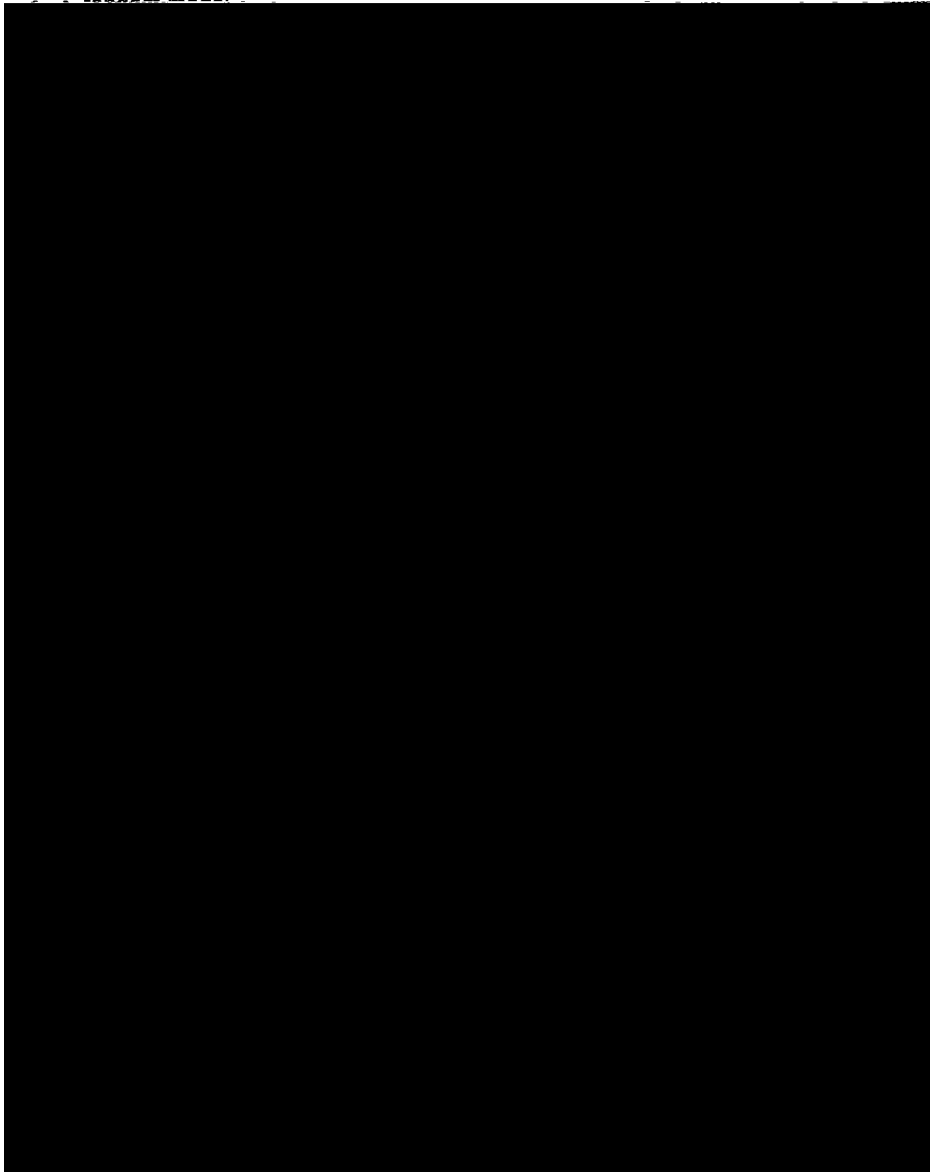
That organisms are particularly sensitive to such unanticipated, noncontingent events is shown by two basic principles of learning: habituation and Pavlovian conditioning.

Wise, M. (1971) ...
... ..





→ subject



rate component, as in Neuringer (1986). The word
CHAOTICS was on the screen in the first component, the
word STOCHASTICS was on during the other,]TJ/F03 3 123 421 Tm[(CH) -32e

same logistic-difference equation that a model did, they were out of phase and independent. If chaotic responding is memory based, then the four independent sequences would be expected to interfere with one another; that is, approximations to the four chaotic models would be lower than when only a single chaotic output was required, as in Neuringer and Voss (1993). That was exactly the finding. Performances by the three subjects were significantly degraded during the four-segment phase. To put it simply, chaotic responses interfered with one another.

A different pattern of results was seen in the stochastics portion of the experiment. The same interference procedure was used, with four independent stochastic sequences required in the four different color conditions. As in Neuringer (1986), subjects were required to satisfy eight different statistical tests of randomness, and to do this independently in each of the four phases. (If responses in any two or more of the four stochastic phases became correlated above a minimal level, responses were considered to be incorrect, thereby prohibiting repetition of a single sequence in two or more of the

Operant variability has structure as well and, as for all operants, that structure is due partly to the organism itself and partly to the reinforcement contingencies. The research described throughout this article has provided examples of the structure of variability, generally in the form of sets of four or eight responses across L and R operanda. But the structure of variations can be specified more precisely. For example, Mook and her colleagues (Mook et al., 1993; Mook & Neuringer, 1994) reinforced rats for varying four response sequences across L and R levers under a lag 1 contingency. Unlike in previous studies, however, the acceptable class was further constrained so that only sequences beginning with two R responses (RLL, RRL, RRLL, and RRR) were reinforced. The rats learned to vary their sequences within the imposed limitations; that-24 (r) -97 () JTJ1 024 () 2 -6 (y) -20000

jects. A second group, the repeat group, received the same rewards for describing common uses of the same objects. In a later test, all of the children were asked to draw pictures incorporating a circle, and the group that had previously

for different operants. RVV might best be understood by analogy to the concepts of speed and acceleration. Both variability and speed range from low to

ing reinforcement contingencies with... as voluntary. "Voluntary" implies potential... dence from stimulus-response or response-reinforcer determination. According to this theory, both explainability and unpredictability are necessary attributes of voluntary acts.

How, though, can behaviors be simultaneously explainable and unpredictable? Reinforcement contingencies play two essential roles. Reinforcement (together with genes, prior experiences, and current environment) helps to determine the set of possible behaviors from which a voluntary response is chosen. Reinforcement (together with the other contributors specified above) also helps to determine the level of variability within the class. Thus, both instances comprising a class and level of variability within that class can be predicted—again, given sufficient knowledge. However, the individual response is at least sometimes (or relatively) unpredictable which the response stochastically emerges is sometimes

iors and thoughts may help to engender what Lange (1989, 2000) has referred to as mindful living—that is, nonautomatic, voluntary engagement, with beneficial effects in different areas, including learning. The importance of this is that it is a process that can be taught, learned, maintained, and modified in everyday life, and that explicit variations may have important consequences.

Temp (1052540) Temp (12540) Temp (140) Temp (18) Temp (739008573) Temp (5) -4 (s) -48 () -77102 Temp (578) Temp (70) -24

Duncan, 1998; Evans & Graham, 1980; Neuringer & Voss, 2002). It is unclear at present how attention influences the different processes underlying operant

and emergence of new forms in children's blockbuilding. *Journal of Applied Behavior Analysis*, 6, 209-217.

Gorka, E. (1993). Within session effects of ethanol on reinforced behavioral variability. Unpublished Ph.D. thesis, Rice College.

Gottlieb, G. (1992). *Individual development and evolution*. Oxford: Oxford University Press.

Grott, R., & Neuringer, A. (1974). *Journal of Experimental Psychology*, 83, 1-30.

Mullins, M., & Rincovec, A. (1985). Comparing autistic and normal children along the dimensions of reinforcement maximization, stimulus sampling, and responsiveness to extinction. *Journal of Experimental Child Psychology*

- Mowrer (Eds.), *Contemporary learning theories: Instrumental conditioning theory and the impact of biological constraints on learning* (pp. 237-275). Hillsdale, NJ: Erlbaum.
- Tremont, P. J. (1984). Variability of force and interresponse time under random interval reinforcement schedules. *Behavioural Processes*, **9**, 413-420.
- Van der Linden, M., Beerten, A., & Pesenti, M. (1998). Age related differences in random generation. *Brain & Cognition*, **38**, 1-16.
- van der Meer, A. L. H., van der Weel, F. R., & Lee, D. N. (1995). The functional significance of arm movements in neonates. *Science*, **267**, 693-695.
- Van Hest, A., van Haaren, F., & van de Pol, N. E. (1989). Operant conditioning of response variability in male and female Wistar rats. *Physiology & Behavior*, **45**, 551-555.
- Volmer, T. R., Iwata, B. A., Zarccone, J. R., Smith, R. G., & Mazalowski, J. L. (1993). The role of attention in the treatment of attention-deficit disorder. *Journal of Abnormal Child Psychology*, **21**, 1-16.