

History effects on induced and operant variability

ALESSANDRA DA SILVA SOUZA AND JOSELE ABREU-RODRIGUES
Universidade de Brasília, Brasília, Brazil

AND

ANA AMÉLIA BAUMANN
Washington University, St. Louis, Missouri

Two experiments evaluated history effects on induced and operant variability. College students typed three-digit sequences on a computer keyboard. Sequence variability was induced (by no reinforcement or variation-independent reinforcement) or reinforced (by variation- or repetition-dependent reinforcement). Conditions with induced and operant variability were presented according to a reverse between-groups design. In Experiment 1, we examined transitions from the variation or repetition contingencies to no reinforcement, and vice versa. In Experiment 2, the variation or repetition contingencies were followed or preceded by variation-independent reinforcement. The results showed that (1) a history of no reinforcement impaired operant variability learning; (2) induced variability levels were higher and lower after a history of reinforcement for variation and repetition, respectively; (3) repetition was more easily disrupted by no reinforcement and independent reinforcement than was variation; and (4) response variability and stability were a function of past and current reinforcement conditions. These results indicate that reinforcement history influences both induced and operant variability levels.

Behavioral variability is influenced by the environment (Neuringer, 2002, 2003, 2004). One source of influence comes from exposure to schedules of reinforcement. When reinforcement is plentiful, behavior usually becomes stereotyped (e.g., under a continuous schedule of reinforcement, CRF; Schwartz, 1980, 1982). When the frequency of reinforcement is reduced (e.g., under intermittent schedules; Eckerman & Vreeland, 1973; Gharib, Gade, & Roberts, 2004), or reinforcement is withheld (e.g., under extinction; Antonitis, 1951; Morgan & Lee, 1996; Stokes, 1995), variability increases in comparison with that observed in the CRF schedule. This increase in variability is said to be induced, rather than reinforced, because there is no contingent relation between variability and reinforcer presentation or omission.

The second source of environmental control is reinforcement. Behavioral variability, as with other behavioral dimensions (e.g., force, topography, duration, rate), is sensitive to operant contingencies. For example, variability is greater when it is required for reinforcement than in the absence of such a requirement (e.g., Page & Neuringer, 1985). In addition, the degree of variation can be precisely controlled by reinforcement contingencies, so that requirements of low, intermediate, and high variability generate the corresponding level of variation (Machado, 1989; Stokes, 1999; Wagner & Neuringer, 2006). More-

over, studies show that discriminative stimuli can affect the probability of varying as opposed to repeating (Denney & Neuringer, 1998; Page & Neuringer, 1985; Ward, Kynaston, Bailey, & Odum, 2008).

A large body of evidence indicates that responding is determined by both past and current contingencies of reinforcement (cf. Lattal & Neef, 1996; Wanchisen & Tatham, 1991). Accordingly, some studies have indicated that past exposure to conditions that induce variability—and exposure to variation and repetition contingencies of reinforcement—alters the degree of variation in a subsequent condition. For example, Neuringer, Kornell, and Olufs (2001) reported that extinction-induced variability in rats was greater after a variation than after a repetition history. Interestingly, when the degrees of variation during training and extinction were compared, increases in variability were found to be lower after the variation than after the repetition training, indicating that repetition was more disrupted by extinction than was variation. Another interesting finding was a mix of variability and stability. That is, extinction-induced variation was characterized by an increase in the frequency of sequences that were rarely emitted during the variation and repetition training. Nevertheless, the ordering of sequence preference—from the most to the least preferred one—found during both trainings was maintained during extinction.

A. Souza, a.souza@psychologie.uzh.ch

One study evaluated history effects by promoting transitions from induced to operant variability conditions, and vice versa. In the investigation performed by Maes (2003), college students were divided into four groups. In Experiment 1, one group was exposed to a variation contingency followed by a no-reinforcement condition (i.e., extinction), whereas a second group experienced the inverse order. In Experiment 2, instead of no reinforcement, the variation contingency was followed or preceded by variation-independent reinforcement for two additional groups. In the absence of an experimental history, variability was higher under the variation contingency than under the no-reinforcement and variation-independent reinforcement conditions. With a history of no reinforcement, but not of variation-independent reinforcement, the variation contingency produced lower levels of variability than without that history, suggesting that the exposure to no reinforcement may impair the subsequent acquisition of operant variation. Finally, with a history of variation contingency, variation was greater during the variation-independent reinforcement than with no such history. Similarly to Neuringer et al. (2001), Maes found an increase in the frequency of rarely emitted sequences and maintenance of the ordering of sequence preference.

In sum, Neuringer et al. (2001) investigated the variation induced by no reinforcement after a history of variation and repetition contingencies. Behavioral variability induced by variation-independent reinforcement was not evaluated. Maes (2003), on the other hand, reported the effects of a history of no reinforcement and of variation-independent reinforcement on variability learning. Repetition learning, however, was not assessed. Thus, both studies left some questions unanswered. The present study aimed to provide a broader assessment of historical variables on behavioral variability by investigating the history effects of both variation and repetition contingencies on the variability induced by no reinforcement and variation-independent reinforcement, as well as the history effects of these last two conditions on operant variation and repetition.

More specifically, to replicate and extend the previous findings, we studied transitions from conditions that induce variability (i.e., no reinforcement and variation-independent reinforcement) to operant contingencies of variation or repetition, and vice versa, using a reversal design. College students were requested to type three-digit sequences. Half of the participants were trained to produce varied sequences, whereas the other half were trained to repeat a specific sequence. In Experiment 1, the variation or repetition contingencies were followed by no reinforcement for two groups of participants, whereas the reverse order was used with two additional groups. In Experiment 2, instead of no reinforcement, the variation or repetition contingencies were followed by a variation-independent reinforcement condition, or vice versa. This design allowed the following assessments: history effects on the acquisition and disruption of operant variability; history effects on the variability induced by no reinforcement and variation-independent reinforcement; and the

mix of response variability and stability produced by different contingency transitions.

METHOD

Participants

One hundred and nine undergraduate students from the Universidade de Brasília (Brasília, Brazil) participated in this study. Data from 29 participants did not reach learning criterion (described below) and their data were discarded (17 from the variation subgroups, 12 from the repetition subgroups). Data from 80 participants (51 women and 29 men) were included in the analysis (40 in each experiment). The participants ranged in age from 17 to 28 years old ($M = 20.2$). Participants read and signed an informed consent form. Their participation consisted of one 40-min session. All participants earned extra credit in introductory psychology classes. Points earned during the task were converted into chances to win a cash prize (approximately \$25) at the conclusion of the study.

Apparatus

The study was conducted in a room (2.30 × 1.82 m) with partial acoustic insulation. The room contained a table, a chair, an IBM-compatible personal computer, and a printer. The experiment was run by a program written in Visual Basic 6 that controlled stimulus presentations and registered keyboard responses.

Design and Procedure

All participants read the following instructions at the beginning of the experiment. The instructions were written in Portuguese and translate to English as follows:

This is a learning experiment. You will be working on this computer throughout the experiment. You will be required to execute a task and will receive points for your performance. Your task is to type sequences consisting of three digits, using the keyboard keys numbered 1, 2, and 3. Each keypress will produce a yellow circle on the screen. This will allow you to keep track of the number of responses you have already made. When you finish typing a sequence, push the Enter button or the space bar. You may type any digit combination, such as 123, 331, 212, and so on. You might discover which sequences produce points. Try to earn as many points as possible. For each correct sequence, you will receive 10 points, and for each 100 points, you will receive a coupon that is worth a chance to earn a prize at the end of the experiment. You will be able to keep track of the number of sequences already typed and the number of coupons you have accumulated. You will be asked to type approximately 900 sequences; therefore, try to work at a steady pace. If you are ready, you can start the experiment by clicking with the mouse on the OK that appears on the screen.

At the start of each trial, the monitor showed a black screen with the word "Sequence" written on the top. In addition, two counters were visible at the bottom of the screen: One counter (on the left) presented the number of trials already completed, and the other (on the right) the number of coupons accumulated. Participants were required to emit three-response sequences by pressing digits 1, 2, and/or 3 on the keyboard. There were 27 possible different sequences. As the participant typed the digits, yellow circles were presented, from the left to the right, in a row above the word "Sequence." If a sequence met the reinforcement criterion, the pressing of the Enter key or the space bar was followed by feedback ("You won 10 points"), a smiley face, and the total number of earned points (hereafter called "reinforcers") on a white screen for 1 sec. None of these reinforcers were produced by noncriterion sequences. Following the production of each sequence (or the reinforcement feedback, when it occurred), a new trial began.

Participants were randomly assigned to one of two groups: variation or repetition. Each group was subdivided into two subgroups ($n = 10$) in each experiment. Hence, in Experiment 1, 40 participants were distributed across four experimental subgroups, and, in Experiment 2, another set of 40 participants was also assigned to four subgroups. Both experiments used ABA and BAB designs, and phase changes were not signaled. The A phase was either a variation (Var) or a repetition (Rep) contingency, depending on the individual's subgroup (variation or repetition group, respectively). The B phase corresponded to no reinforcement (NoS^r; Experiment 1) or to variation-independent (Ind) reinforcement (Experiment 2). Subgroups were named according to the order of exposure to the experimental conditions through the three phases—with the first, second, and third abbreviation referring to Phases 1, 2, and 3, respectively (see Table 1). The third phase corresponded to the reexposure to the same reinforcement condition introduced in Phase 1.

Each phase lasted 300 trials, except for the last phase of the Var-NoS^r-Var and Rep-NoS^r-Rep subgroups (Experiment 1), and of the Var-Ind-Var and Rep-Ind-Rep subgroups (Experiment 2). For these subgroups, the last phase ended when the number of reinforcers was equal to that obtained in Phase 1 or after 300 trials, whichever occurred first. Each phase is described below.

Variation (Var). In this phase, a sequence was followed by reinforcement if it satisfied two variability criteria: (1) The current sequence had to differ from each of the preceding two emitted sequences (lag 2 criterion), and (2) the weighted relative frequency of the current sequence had to be less than or equal to a certain threshold (cf. Denney & Neuringer, 1998). The relative frequency was computed by dividing the total number of occurrences of each sequence by the total number of completed sequences (trials). To weight recently produced sequences more than past sequences, after each reinforcer delivery, the relative frequency of the 27 sequences was multiplied by a weighting coefficient ($w = .95$) that exponentially decreased the contribution of past sequences. The weighted frequency of the current sequence was compared with the threshold value to determine whether this sequence was to be reinforced. If the weighted relative frequency was less than or equal to the threshold (and the lag 2 requirement was satisfied), a reinforcer was delivered; otherwise, the sequence was considered a noncriterion one, and no feedback was provided. The threshold was set to .02 throughout the study. In the beginning of each phase, all sequences' counters were set to zero (thus, the first emission of each sequence was followed by reinforcement).

Repetition (Rep). In this phase, every emission of the sequence 231 (the first presentation of the Rep phase) or 132 (the second presentation of the Rep phase) was followed by reinforcement.

No reinforcement (NoS^r). In this phase, none of the emitted sequences produced reinforcers.

Variation-independent reinforcement (Ind). In this phase, there was no contingent relation between sequence variation (or repetition) and reinforcer delivery. Hence, 50% of the produced sequences were followed by reinforcement, and 50% were not, independently of the degree of variation. The delivery of reinforcers was based on a preprogrammed list that randomly assigned reinforcement and no reinforcement across trials—and that guaranteed that no more than three reinforcement (or no-reinforcement) trials occurred in a row.

Data Analysis

Data from each phase were divided into blocks of 50 trials, yielding six blocks per experimental phase. For each 50-trial block, several behavioral measures were analyzed:

1. The percentage of sequences that met the variability (MetVar) or the repetition (MetRep) criteria in all phases for the variation and repetition groups. The MetVar and MetRep percentages were computed according to the following formula: [number of trials in which the variability (or repetition) criterion was met/total number of trials] * 100.

Given that the MetVar takes into consideration whether the frequency of the just produced sequence was below or above the threshold, it provides an assessment of the operant variability reinforced during the variation phase.

2. The overall index of sequence variability (U value). U values were computed according to the following equation (Miller & Frick, 1949):

$$\frac{-\sum \{RF_i \times [\log(RF_i) / \log(2)]\}}{[\log(n) / \log(2)]}$$

where RF is the relative frequency of the sequence i (for $i = 1$ to n), and n is the number of all possible sequences (27). If each of the 27 possible sequences was produced equally often, then the U value would be equal to 1; if only one sequence was produced, the U value would be equal to 0. In comparison with the MetVar and MetRep values, the U value may be considered a molar measure of variability. It takes into account the likelihood of all possible sequences in a defined set of produced sequences (in the case of the present experiment, a block of 50 trials). Thus, it shows variability on a more global level (blocks), whereas the MetVar is more of a molecular measure of variability because it indicates the degree of variability of each produced sequence.

3. The probabilities of each sequence (sequence frequency/total trials) in the first and second phases. Sequences were ordered from the most to the least probable (considered here as a measure of preference) in the first phase. Sequence probabilities in the second phase were computed in the same order of preference as in the first

Table 1
Reinforcement Conditions in Each Phase of Experiments 1 and 2
for the Variation and Repetition Subgroups

Group	Subgroup	Experimental Phase		
		Phase 1	Phase 2	Phase 3
Experiment 1				
Variation	Var-NoS ^r -Var	Variation	No reinforcement	Variation
	NoS ^r -Var-NoS ^r	No reinforcement	Variation	No reinforcement
Repetition	Rep-NoS ^r -Rep	Repetition	No reinforcement	Repetition
	NoS ^r -Rep-NoS ^r	No reinforcement	Repetition	No reinforcement
Experiment 2				
Variation	Var-Ind-Var	Variation	Independent S ^r	Variation
	Ind-Var-Ind	Independent S ^r	Variation	Independent S ^r
Repetition	Rep-Ind-Rep	Repetition	Independent S ^r	Repetition
	Ind-Rep-Ind	Independent S ^r	Repetition	Independent S ^r

Note—S^r, reinforcers; Var, variation; Rep, repetition; NoS^r, no reinforcement; Ind, variation-independent reinforcers.

phase. Finally, the ratio of each sequence's probabilities in the first and second phases was computed to examine the relation between variability and stability. A ratio of 1.0 indicates no change, whereas ratios greater or smaller than 1.0 indicate increases and decreases in sequence probability, respectively.

Participants who did not reach a minimum percentage (i.e., 25%) of MetVar or MetRep in the last block of the first variation or repetition phases were excluded from the data analysis (learning criterion). Results were tested for significance with a repeated measures ANOVA, one-way ANOVA, or Student's *t* tests. In the repeated measures ANOVA, blocks were the within-subjects factor and subgroups were the between-subjects factor. In most of the repeated measures ANOVA analyses performed, the sphericity assumption was violated. Nevertheless, we reported Greenhouse–Geisser adjusted degrees of freedom only when this affected the *p* value. To correct for the nonsphericity, we also employed Bonferroni's adjustment for multiple comparisons. In addition, eta-squared (η^2) results were provided for the significant effects.

RESULTS

MetVar and MetRep

Figure 1 presents the mean percentage of sequences that met the variability (MetVar) and repetition (MetRep) criteria, and the mean U values in each block of 50 trials for the variation and repetition groups in Experiments 1 and 2. These measures were presented for the first exposure to the operant contingencies (circles) and the inducing phases (squares) and for the reexposure (ReExp) to these conditions that occurred in Phase 3.

Experiment 1: Acquisition. As is shown in Figure 1, when the variation contingency was introduced for the first time (Var), a gradual increase in the MetVar was observed for both variation subgroups, suggesting a learning curve. Indeed, the repeated measures ANOVA revealed a main effect of block [$F(2.39, 43.09) = 28.286, p < .001, \eta^2 = .54$], and of block \times subgroup interaction [$F(2.39, 43.09) = 6.337, p = .002, \eta^2 = .12$], but not a main effect of subgroup. Pairwise comparisons showed a significant difference between the fifth block and the remaining blocks (except the first one) and a significant difference between the last block and all remaining blocks ($p < .05$). An independent samples *t* test was performed with data from the last block, and it revealed that the Var-NoS^r-Var subgroup obtained a higher MetVar ($M = 86.2, SD = 13.1$) than the NoS^r-Var-NoS^r subgroup ($M = 65.2, SD = 23.3$) [$t(14.21) = 2.483, p = .026$]. Thus, there was evidence that after a history of no reinforcement, participants presented a lower MetVar than in the absence of such a history.

During the first presentation of the repetition contingency (Rep), a gradual increase in the MetRep for both repetition subgroups was also observed, and accordingly, only the main effect of block was found to be significant [$F(2.62, 47.16) = 38.813, p < .001, \eta^2 = .66$]. Pairwise comparisons showed that the first and second blocks were different from all remaining blocks ($p < .05$). Therefore, performance in the repetition phase was not affected by a history of no reinforcement.

Experiment 1: Reacquisition. Reintroducing the variation and repetition contingencies in the third

phase increased the MetVar and MetRep, respectively (ReExp phase; see Figure 1). Performance in the first Var and Rep phases was compared with performance in the ReExp phases—that is, for the Var-NoS^r-Var and Rep-NoS^r-Rep subgroups—by means of a two-factor (block and phase) repeated measures ANOVA. For the Var-NoS^r-Var subgroup, only the first three blocks of each phase were included in the analysis because most participants finished the experiment by the third block of the ReExp phase. There was a significant effect of block [$F(2,18) = 4.150, p = .033, \eta^2 = .01$], phase [$F(1,9) = 185.928, p < .001, \eta^2 = .74$], and block \times phase interaction [$F(2,18) = 29.035, p < .001, \eta^2 = .14$]. Pairwise comparisons showed that higher MetVar values were obtained in the ReExp than in the Var phase.

For the Rep-NoS^r-Rep subgroup, five blocks of each phase were included in the analysis because most participants had finished the experiment by this block, and a significant effect of block was found [$F(4,36) = 27.589, p < .001, \eta^2 = .55$]. Pairwise comparisons revealed a significantly lower MetRep in the first block than in the subsequent blocks ($p < .05$). Neither the effects of subgroup nor of block \times phase interaction were significant.

Experiment 1: No reinforcement. Comparison of the NoS^r phase of both variation subgroups showed only a main effect of block [$F(5,90) = 32.804, p < .001, \eta^2 = .63$] (significant difference between the first and the remaining blocks, $p < .001$). This result suggests that prior exposure to the variation contingency had no effect on the MetVar during the no-reinforcement phase. The comparison of the NoS^r phase of the Var-NoS^r-Var with the ReExp phase of the NoS^r-Var-NoS^r—that is, both after a history of variation contingency—yielded a main effect of block \times subgroup interaction [$F(5,90) = 11.112, p < .001, \eta^2 = .24$]. Pairwise comparisons showed that the first block was different from all other blocks ($p < .001$), and that the Var-NoS^r-Var subgroup presented a higher MetVar than the NoS^r-Var-NoS^r subgroup ($p < .001$). Comparison of the NoS^r phase of both repetition subgroups, and of the NoS^r phases after the repetition contingency (i.e., in the ReExp phase) did not yield significant effects of block, subgroup, or block \times subgroup interaction.

Experiment 2: Acquisition. During the Var phase (Figure 1), a gradual increase in the MetVar was observed for both variation subgroups, and the repeated measures ANOVA showed only a main effect of block [$F(5,90) = 36.847, p < .001, \eta^2 = .66$]. Pairwise comparisons showed a significant difference between the fifth block and all remaining blocks (except the first one) and between the last block and all other blocks ($p < .05$). Thus, there was no evidence that a history of variation-independent reinforcement affected acquisition during the variation contingency.

During the Rep phase, a gradual increase in the MetRep was observed for both repetition subgroups, and, indeed, only the effect of block was found to be significant [$F(5,90) = 39.173, p < .001, \eta^2 = .66$]. Pairwise comparisons also showed that the first and second blocks were significantly different from all other blocks ($p < .05$).

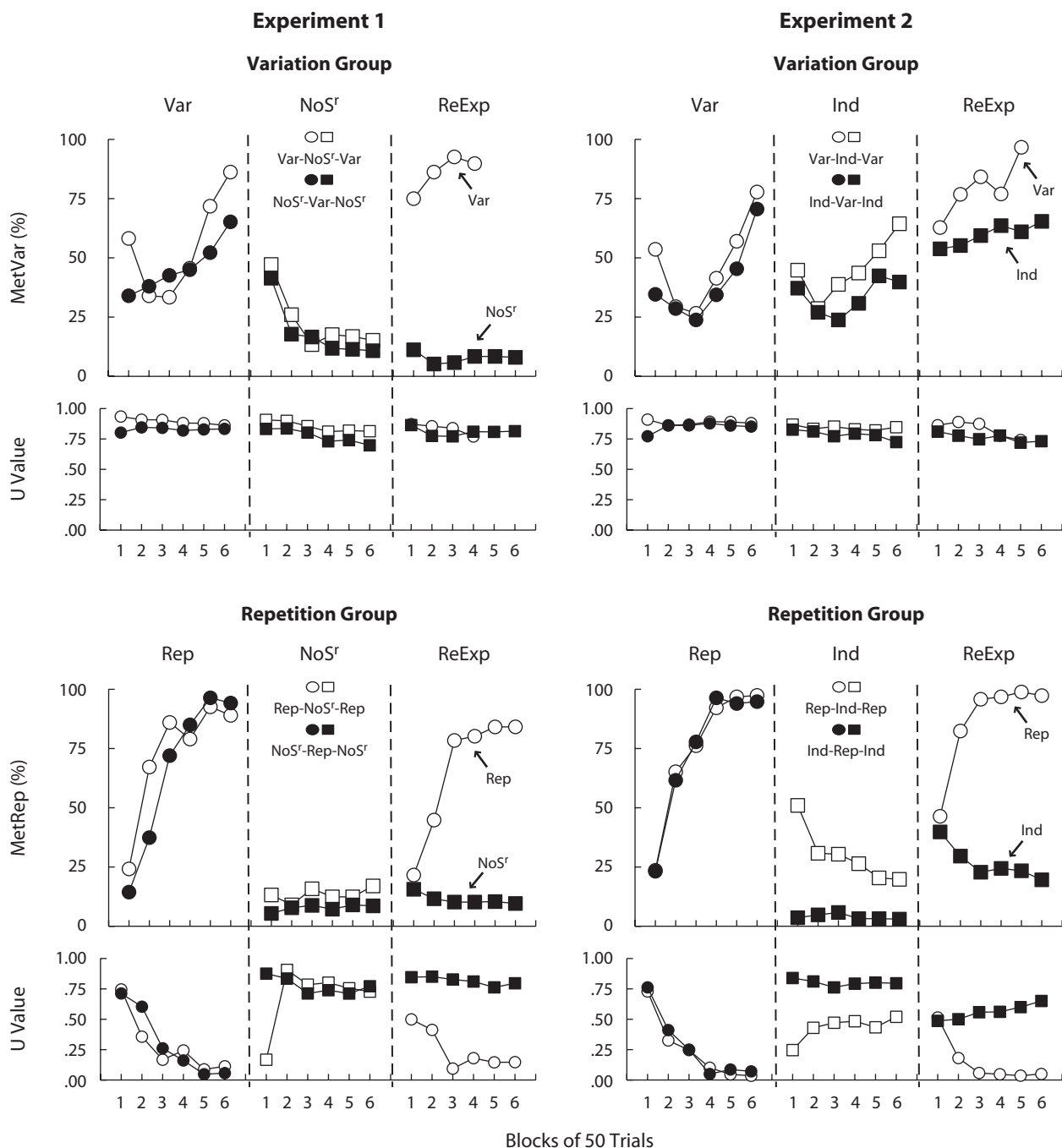


Figure 1. Mean percentages of sequences that met the variability (MetVar) and repetition (MetRep) criteria (top panel) and mean U values (bottom panel) in each block of 50 trials for the variation and repetition groups in Experiments 1 and 2. These measures were presented for the first exposure to the operant contingencies (circles) and the inducing phases (squares) and for the reexposure (ReExp) to these conditions that occurred in Phase 3. The black symbols indicate the subgroups exposed to the operant contingency (variation and repetition contingencies) in the very first phase, and the open symbols indicate the subgroups exposed to the variation-inducing conditions (no reinforcement and independent reinforcement) in the first phase.

.05). This result indicates that a history of variation-independent reinforcement did not affect performance in the repetition phase.

Experiment 2: Reacquisition. Reintroducing the variation and repetition phases rapidly increased the MetVar and MetRep, respectively (ReExp phase; see

Figure 1). Performance in the Var (or Rep) and ReExp phases of the Var-Ind-Var (or Rep-Ind-Rep) subgroup was compared with a two-factor (block and phase) repeated measures ANOVA. For the Var-Ind-Var subgroup, only three blocks were included in this analysis, again because most participants had finished the ReExp phase by the

third block. There was a main effect of phase [$F(1,9) = 34.747, p < .001, \eta^2 = .59$] and block \times phase interaction [$F(2,18) = 46.860, p < .001, \eta^2 = .18$]. Pairwise comparisons showed a significant difference between performance in the Var and ReExp phases ($p < .001$). For the Rep-Ind-Rep subgroup, the first five blocks of each phase were included in the analysis, yielding a main effect of block [$F(1.54, 13.88) = 15.494, p = .001, \eta^2 = .26$] and of block \times phase interaction [$F(2.55, 22.96) = 3.445, p = .018, \eta^2 = .09$]. Pairwise comparisons showed a significant difference between the first block and the remaining blocks ($p < .05$).

Experiment 2: Variation-independent reinforcers.

During the Ind phase of the variation group, intermediate MetVar values were observed. For the repetition group, the effects of the Ind phase depended on the previous history of repetition (i.e., an intermediate MetRep for the Rep-Ind-Rep subgroup, and a low MetRep for the Ind-Rep-Ind subgroup; see Figure 1).

Comparison of the Ind phase between the variation subgroups showed a main effect of block [$F(5,90) = 12.818, p < .001, \eta^2 = .39$] and subgroup [$F(1,18) = 6.052, p = .024, \eta^2 = .25$], but not of block \times subgroup interaction. Pairwise comparisons indicated that the first block was significantly different from the second and third blocks ($p < .05$), and the last block was different from the second, third, and fourth blocks ($p < .05$). In addition, MetVar values after a history of variation (i.e., for the Var-Ind-Var subgroup) were higher than in the absence of this history (for the Ind-Var-Ind subgroup; $p = .024$). Comparison of the Ind phases of the Var-Ind-Var subgroup with the ReExp phase of the Ind-Var-Ind subgroup—both after a history of variation contingency—showed only a main effect of block [$F(1.94, 34.92) = 4.982, p = .013, \eta^2 = .20$]. Pairwise comparisons showed a significant difference between the last block and the second one ($p = .036$).

Comparison of the Ind phase between the repetition subgroups indicated a main effect of block [$F(1.90, 34.21) = 3.906, p = .032, \eta^2 = .15$], subgroup [$F(1,18) = 19.354, p < .001, \eta^2 = .52$], and block \times subgroup interaction [$F(1.90, 34.21) = 3.595, p = .040, \eta^2 = .14$]. Pairwise comparisons indicated that the first block was significantly different from the fourth block ($p < .05$), and that MetRep values were higher after a history of repetition ($p < .001$). Comparison of the Ind phase of the Rep-Ind-Rep and the ReExp phase of the Ind-Rep-Ind subgroup—that is, the Ind phase after a history of repetition contingency—showed only a main effect of block [$F(2.17, 39.14) = 7.953, p = .001, \eta^2 = .30$]. Pairwise comparisons indicated a significant difference between the first block and the remaining ones ($p < .05$).

U Value

Experiment 1. For the variation group, U values were higher during the variation contingency than during the no-reinforcement condition in the first phase (i.e., Var phase vs. NoS^r phase between subgroups; see Figure 1). The repeated measures ANOVA confirmed only a main effect of subgroup [$F(1,18) = 11.312, p = .003, \eta^2 =$

.39], thus indicating that higher variability levels were observed under the variation contingency. The comparison of the Var phase between subgroups showed that the NoS^r-Var-NoS^r subgroup presented a lower U value than the Var-NoS^r-Var subgroup [$F(1,18) = 12.805, p = .002, \eta^2 = .42$]. Neither the effects of block nor block \times subgroup interaction were significant.

During the NoS^r phase, similar U values were observed—regardless of whether there was a history of variation contingency or not—as long as no main effect of subgroup (or of block \times subgroup interaction) was found by the repeated measures ANOVA. However, the effect of block was significant [$F(2.51, 45.23) = 3.759, p = .023, \eta^2 = .17$] and pairwise comparisons showed the first and the last blocks to be different ($p < .05$). The comparison of the no-reinforcement phases presented after the variation phase yielded no significant effects.

For the repetition group, U values varied in accordance with the reinforcement phase. During the first phase of both repetition subgroups, a higher U value was observed in the no-reinforcement phase than in the repetition phase (see Figure 1). Accordingly, the effects of block [$F(5,90) = 19.821, p < .001, \eta^2 = .44$], subgroup [$F(1,18) = 42.115, p < .001, \eta^2 = .70$], and block \times subgroup interaction [$F(3.11, 55.91) = 7.541, p < .001, \eta^2 = .17$] were significant. Pairwise comparisons showed a significant difference between the first block and all remaining blocks ($p < .05$) and between the second block and the third and fifth blocks ($p < .05$). During the Rep phase, only a significant effect of block was obtained [$F(5,90) = 35.264, p < .001, \eta^2 = .64$]. Pairwise comparisons indicated a significant difference between the first and second blocks and the remaining blocks ($p < .05$).

The NoS^r phase maintained similar U values for both repetition subgroups, except for the first block (see Figure 1). Only the effects of block [$F(5,90) = 13.383, p < .001, \eta^2 = .24$] and of block \times subgroup interaction [$F(5,90) = 24.312, p < .001, \eta^2 = .44$] were significant. Pairwise comparisons showed a significant difference between the first block and the second, fourth, and sixth blocks ($p < .05$). Comparison of the no-reinforcement phases presented after the repetition phase revealed a main effect of block [$F(5,90) = 18.315, p < .001, \eta^2 = .32$], subgroup [$F(1,18) = 8.056, p = .011, \eta^2 = .31$], and block \times subgroup interaction [$F(3.421, 61.572) = 20.995, p = .011, \eta^2 = .37$]. Pairwise comparisons showed a significant difference between the first block and the remaining blocks and also between the second block and the last block ($p < .05$), and that the NoS^r-Rep-NoS^r subgroup (in the ReExp phase) presented higher U values than the Rep-NoS^r-Rep subgroup (in the First NoS^r phase; $p < .05$).

Experiment 2. Figure 1 shows that U values were higher for the variation group during the variation phase than during the variation-independent phase (first phases compared between subgroups), and the repeated measures ANOVA confirmed only a main effect of subgroup [$F(1,18) = 18.311, p < .001, \eta^2 = .50$]. Comparison of the Var phase did not show a main effect of block or of subgroup, but the block \times subgroup interaction was sig-

nificant [$F(3.45, 62.12) = 3.819, p = .011, \eta^2 = .17$]. Inspection of Figure 1 suggests that during the Ind phase, higher U values were obtained when this phase was introduced after a history of variation (i.e., for the Var-Ind-Var subgroup) than in the absence of such history. This effect was confirmed by the repeated measures ANOVA [$F(1,18) = 5.180, p = .035, \eta^2 = .22$; subgroup effect]. When we compare the variation-independent phases introduced after a variation phase, intermediate MetVar values were observed for both subgroups and the repeated measures ANOVA yielded no significant results, thus indicating that repeated exposure to the variation-independent phase had no effects on the variability induced by this condition.

For the repetition group, U values varied according to the reinforcement phase. The comparison of performance in the very first phase between the Rep-Ind-Rep and Ind-Rep-Ind subgroups—that is, between the Rep and Ind phases—revealed significant effects of block [$F(5,90) = 18.164, p < .001, \eta^2 = .36$], subgroup [$F(1,18) = 96.067, p < .001, \eta^2 = .84$], and block \times subgroup interaction [$F(5,90) = 14.178, p < .001, \eta^2 = .28$]. Pairwise comparisons indicated that the first block was different from all the other blocks ($p < .05$). The significant subgroup effect indicates that a higher U value was observed during the variation-independent phase than during the repetition phase ($p < .001$). Comparison of the Rep phase between subgroups confirmed only a main effect of block [$F(5,90) = 42.317, p < .001, \eta^2 = .70$]. Pairwise comparisons indicated that the first and second blocks were different from the remaining blocks ($p < .05$).

The Ind phase produced different U values between subgroups, and, accordingly, the main effects of subgroup [$F(1,18) = 26.019, p < .001, \eta^2 = .59$] and of block \times subgroup interaction [$F(1.83, 32.88) = 4.825, p = .017, \eta^2 = .19$] were significant. Pairwise comparisons indicated that U values were lower after a history of repetition ($p = .001$). The comparison of the variation-independent phases presented after the repetition phase revealed only a main effect of block [$F(2.46, 44.24) = 5.186, p = .006, \eta^2 = .21$]. Pairwise comparison showed a significant difference between the first and the last blocks ($p < .05$).

Disruption of Operant Variation and Repetition

Experiment 1. Figure 1 shows that withholding reinforcement after a history of variation or repetition contingency reduced the MetVar and MetRep. Moreover, this reduction seemed to be lower in the first block of trials for the Var-NoS^r-Var subgroup than in the Rep-NoS^r-Rep (NoS^r phase), the NoS^r-Var-NoS^r, and the NoS^r-Rep-NoS^r (ReExp phases) subgroups. Indeed, when the relative decrease (the ratio of the first block of the no-reinforcement phase and the last block of the prior variation or repetition phase) was compared with a one-way ANOVA, a significant effect was obtained [$F(3,36) = 30.899, p < .001, \eta^2 = .72$]. A Bonferroni test confirmed that the Var-NoS^r-Var subgroup presented a lower decrease in the first block than did the other subgroups ($p < .001$).

Experiment 2. Variation-independent reinforcement also decreased the MetVar and MetRep after a history of variation and repetition contingency, respectively. When the relative decrease (first block of variation-independent phase/last block of prior phase) was compared between subgroups (by a one-way ANOVA), no significant differences were found. Nevertheless, Figure 1 shows that the MetVar tended to increase, whereas the MetRep decreased, across blocks. Because of this result, we computed the relative decrease for the last block (last block of the variation-independent phase/last block of the prior phase), and compared the result using a one-way ANOVA. A significant effect of subgroup was found [$F(3,26) = 11.111, p < .001, \eta^2 = .48$]. A Bonferroni test showed that the variation subgroups presented a lower decrease than the repetition subgroups ($p < .01$) in the last block.

Variability and Stability in the Order of Sequence Preference

Figure 2 depicts the mean probability of production of each of the 27 sequences in the first two phases (Var or Rep, white dots; and NoS^r or Ind, black dots) for each subgroup, and the mean ratio of each sequence probability (gray squares) in the second phase in relation to its probability in the first phase (i.e., Phase 2/Phase 1). Sequences were ordered from the most to the least frequent (considered here as a measure of preference) in the first phase. Data from NoS^r-Rep-NoS^r and Ind-Rep-Ind subgroups are not presented. Given that those subgroups experienced a shift to a repetition contingency and that during this contingency only one sequence was produced in most trials, the analysis was not very informative.

Experiment 1. Shifting from the variation to the no-reinforcement phase (i.e., for the Var-NoS^r-Var subgroup) increased the probability of the least preferred sequences, thus indicating variability, but the ordering of sequence probabilities did not change, thus showing stability. The shift from the no-reinforcement to the variation phase (i.e., for the NoS^r-Var-NoS^r subgroup) increased the probabilities of several nonpreferred sequences and decreased the probabilities of the most preferred ones, but the ordering of sequence probabilities was also relatively unchanged. Lastly, the shift from the repetition to the no-reinforcement phase (i.e., for the Rep-NoS^r-Rep subgroup) increased the probabilities of all sequences except the repetition sequence, thus showing a large increase in variability. Nevertheless, the repetition sequence was still the most frequently produced during the no-reinforcement condition, showing stability. Therefore, the degree of variability and stability observed depended on both the past and the current phases. Higher stability than variability was observed with shifts from Var to NoS^r; however, higher variability was observed with the shift from NoS^r to Var and from Rep to NoS^r.

Experiment 2. Shifting from the variation to the variation-independent phase (i.e., for the Var-Ind-Var subgroup) slightly increased the probabilities of the least preferred sequences; yet, again, the ordering of sequence probability did not change. The shift from the

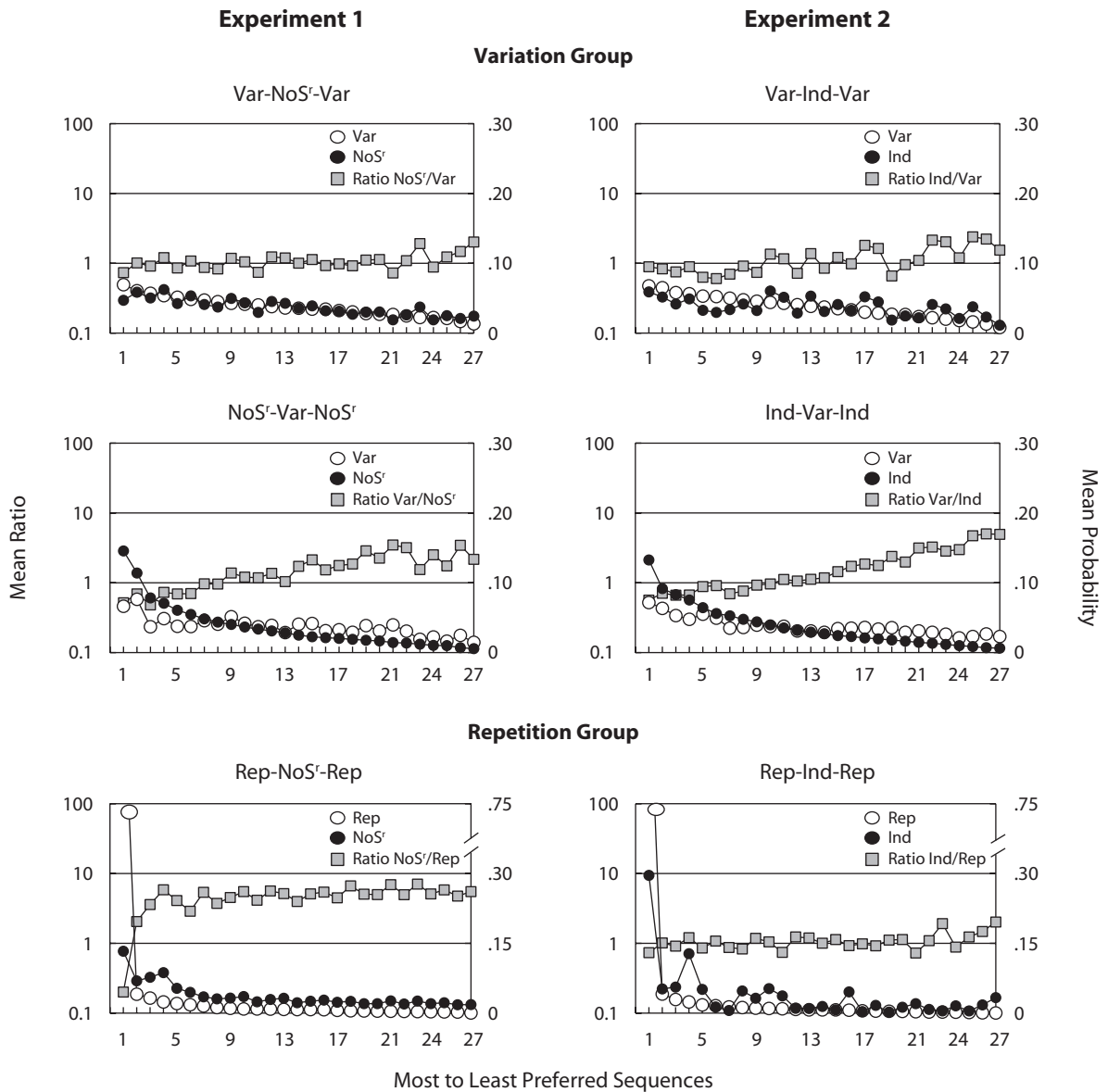


Figure 2. Mean probabilities of each of the 27 possible sequences (secondary y-axis) and mean ratio (i.e., second phase/first phase) of each sequence probability (primary y-axis). Probabilities are depicted separately for the variation and repetition phases and for the no-reinforcement (Experiment 1) and variation-independent reinforcement (Experiment 2) phases. Sequences were ordered from the most to the least preferred in the first phase.

variation-independent to the variation phase (i.e., for the Ind-Var-Ind subgroup) increased the probabilities of a great number of nonpreferred sequences and decreased the probabilities of the most preferred ones; but sequence ordering did not differ between phases. Lastly, shifting from the repetition to the variation-independent phase (i.e., for the Rep-Ind-Rep subgroup) produced a slight increase in the probability of the least preferred sequences and a decrease in the probability of the repetition sequence; but, overall, sequence ordering remained unchanged, showing stability. Similar to the results obtained in Experiment 1, higher stability than variability was observed with the shift from variation to variation

independent, whereas increased variability was observed with the transition from variation independent to variation. Unlike results with no reinforcement, the transition from repetition to variation independent did not produce a high increase in variability, but it maintained performance, indicating stability.

DISCUSSION

The present experiment examined history effects on induced and operant variability. The major findings can be summarized as follows. First, preexposure to a no-reinforcement phase impaired the acquisition of oper-

ant variation but had no detectable effect on the acquisition of a repetitive response. Variation-independent reinforcers, however, did not affect the acquisition of either operant. Second, operant variation was less disrupted than was repetition by no reinforcement and variation-independent reinforcers. Finally, evidence of both variability and stability was observed as a function of changes in reinforcement conditions. Nevertheless, the degree of variability and stability depended on the previous and current conditions in effect. These findings are discussed below.

Acquisition

Overall, reinforcing high and low variability levels increased and decreased variability, respectively, whereas withholding reinforcement decreased the occurrence of the reinforced unit (i.e., MetVar and MetRep). Taken together, these findings demonstrate operant control on variability levels, replicating previous findings (Abreu-Rodrigues, Lattal, Santos, & Matos, 2005; Maes, 2003; Neuringer et al., 2001; Page & Neuringer, 1985; Stokes, 1999).

With regard to history effects, prior exposure to no reinforcement and variation-independent reinforcers had different effects on acquisition of varied responses. No reinforcement, but not variation-independent reinforcement, interfered with the acquisition of operant variation, replicating the findings reported by Maes (2003; see also Hunziker, Yamada, Manfré, & Azevedo, 2006; Saldana & Neuringer, 1998). Maes suggested that the learning interference produced by a history of no reinforcement could be accounted for by the “learned helplessness” phenomenon (cf. Abramson, Seligman, & Teasdale, 1978). This phenomenon is characterized by impairment in learning due to a prior experience with uncontrollable events—that is, situations without a response–consequence contingency. This history of uncontrollability is hypothesized to create an expectation of reduced associability between responses and consequences, thus affecting the organism’s ability to detect future contingent relations. In the present study, participants were exposed to two types of no-contingent relations: consistent absence of reinforcement (the NoS^r phase) and variation-independent reinforcement (the Ind phase). Therefore, if the learned helplessness interpretation were to have been correct, both situations should have impaired learning of varied and repetitive behaviors. However, this was not the case: Only the NoS^r phase had a detrimental effect, and this was restricted to the acquisition of operant variation.

Why, then, did the prior exposure to no reinforcement impair only variability learning? One tentative explanation is based on generalization, or negative transfer, given the similarities between the no-reinforcement and variation phases. During the no-reinforcement phase, because sequences were not followed by reinforcers and as long as the instruction stated that reinforcers would be produced by correct sequences, participants tried to vary their sequences. The variability induced by the absence of reinforcers, however, was not sufficient to satisfy the

variability contingency. When the contingency changed, therefore, participants had to adjust their behavior. Nevertheless, noncriterion sequences were not followed by reinforcers (and this was similar to the prior no-reinforcement phase). Moreover, sometimes the variation engendered by no reinforcement may have produced reinforcers during the variation phase. These features may have delayed the learning of the variability requirement.

Several studies have pointed out a facilitative effect of variation on acquisition of a repetitive response, especially if this response is a difficult one (Grunow & Neuringer, 2002; Neuringer, 1993; Neuringer, Deiss, & Olson, 2000). Thus, one could expect that inducing variability (either by no reinforcement or by presenting response-independent reinforcement) would have promoted learning for the repetition group. This was not the case in the present study, probably due to the easiness of the repetition sequence. Inspection of frequency distributions of sequences for the NoS^r-Rep-NoS^r and Ind-Rep-Ind subgroups (data not shown) revealed that the repetition sequence was not of low probability (and probably not a difficult-to-learn one). In this sense, the repetition sequence may have been quickly learned, and thus, any beneficial effect of variation may have become superfluous. Therefore, it is possible that the conditions arranged in the present study were not well suited for observing the facilitative effects of inducing variability on the acquisition of repetition (see also Maes & van der Goot, 2006). Future investigations should, therefore, examine responses that are more difficult to learn.

No-Reinforcement and Variation-Independent Reinforcement Effects

During the NoS^r phase, the MetVar and MetRep were low, but high U values were observed. On the other hand, during the Ind phase, the MetVar was intermediate and the MetRep was low, but U values were high for both subgroups. Finally, during the Var phase, the MetVar increased across blocks, but the U value was high in all blocks. These results show that the MetVar and the U value may reveal different aspects of behavioral variability. The MetVar was a more sensitive measure of operant variability than the U value, because it showed learning and extinction curves under reinforcement and absence of reinforcement for variation, respectively, whereas the U value was high for all subgroups in spite of the presence or absence of a variation contingency.

The highly differentiated MetVar levels across the no-reinforcement, variation-independent, and variation phases suggest that distinct controlling variables were affecting variability. Variability during the no-reinforcement phase may be characterized as a tendency to use different behavioral alternatives (as shown by the high U value). Nevertheless, when the probability of producing a low-frequency sequence in the current trial is considered (i.e., the MetVar), the observed variability was low. In addition, the variability induced by this condition was not affected by the previous history of reinforcement (see NoS^r phase; Figure 1), suggesting that operant factors may have had little influence.

This pattern of high induced but low operant variability probably occurred because participants tried different behaviors/strategies during the no-reinforcement phase, but those “varied” behaviors may have been embedded in the middle of repetitive chains. To clarify this point, let us re-code each different sequence with a number from 1 to 27. Suppose that in the no-reinforcement phase, the participant produced the sequences 1, 1, 2, 1, 2, 3, 3, 3, 4, 4, 4, 5, 5, and so on, in successive trials. In the variation phase, on the other hand, the participant’s sequences were 1, 2, 4, 3, 5, 1, 2, 3, 4, 5, 2, 3, 1, and so on. Thus, during the no-reinforcement phase, there was sequence variation in the long run, but also several repetitions across successive trials; during the variation phase, however, the participant was more likely to avoid repetitions for many trials in succession.

In the study of Maes (2003), autocorrelations were computed to quantify the extent to which participants were responding systematically (as in our variation example above) or more randomly (more similar to the no-reinforcement pattern above). Maes reported that under the variation contingency, systematic responding was more likely to occur, whereas during the inducing conditions, responding was more random. We also computed autocorrelations and found a similar pattern of results (data not shown). Taken together, these results suggest that induced and operant variability may differ not in the general number of different behavioral alternatives displayed by the organism, but in *how* those different responses are displayed—with repetitions or in a way that maximizes reinforcement.

Variability levels during the first variation-independent phase were in between the induced and operant levels observed during the no-reinforcement and variation phases. This result cannot be entirely explained by reinforcement intermittency during this phase because intermittency is predicted to induce lower variability levels than withholding reinforcement (e.g., Eckerman & Vreeland, 1973; Tatham, Wanchisen, & Hine, 1993). Another complementary explanation comes from the phenomenon of superstitious behavior—that is, responses conditioned or maintained by their adventitious contiguity with reinforcers (Neuringer, 1970; Ono, 1987; Skinner, 1948). Variability levels in the variation-independent phase may have been conditioned superstitiously: No-reinforcement trials induced variation, and such variation was maintained due to the delivery of reinforcers in the remaining trials. This interpretation seems plausible when the MetVar in the very first and the last blocks of the first phase of the NoS^r-Var-NoS^r and Ind-Var-Ind subgroups (see Figure 1) are compared. These subgroups began the experiment with similar MetVar values; however, the MetVar decreased during the no-reinforcement phase and was sustained by variation-independent reinforcers. This interpretation is further supported by the higher MetVar and MetRep values observed during the variation-independent phase that followed the variation and repetition contingencies, in comparison with the MetVar and MetRep observed in the variation-independent phase before those contingencies. In such

cases, variation-independent reinforcers sustained variation or repetition depending on which of those behaviors was already established in the repertory of the individual, thus indicating history effects.

Disruptive Effects

We observed that either the no-reinforcement or the variation-independent phases (both situations lacking an R–S contingency) reduced the occurrence of both operant units (MetVar and MetRep), but this decrease was higher for the repetition group. The higher susceptibility of repetitive behaviors to disrupting events replicates findings from previous studies with nonhuman animals (e.g., Abreu-Rodrigues, Hanna, Cruz, Matos, & Delabrida, 2004; Neuringer, 1991; Neuringer et al., 2001; Odum, Ward, Barnes, & Burke, 2006; Wagner & Neuringer, 2006; Ward, Bailey, & Odum, 2006). Nevertheless, one might want to view our results with caution. One might say that we used only disruptive operations that are known to induce variability, and this might have favored a higher disruption of repetition over variation. Therefore, it would be interesting for future studies to address this issue by means of other disruptive methods.

Variability and Stability in the Order of Sequence Preference

The different transitions between contingencies implemented in the present study produced a mix of sequence variability and stability (Maes, 2003; Neuringer et al., 2001). On the one hand, phase transitions engendered variability, as reflected in the increase in the probabilities of nonpreferred sequences. On the other hand, response structures revealed stability, in that the ordering of the 27 sequences established during the first phase was sustained in the following phase. In general, this mix of variability and stability reflects the effects of both current and past contingencies in determining variability: Current contingencies produced adjustments in behavior, as was observed in the increased probability of rare sequences, whereas past contingencies influenced which sequences were most preferred and which were not. Furthermore, the effects of historical variables were more prominent when the current contingencies were permissive (e.g., during the variation-independent reinforcement condition) than when the actual contingency was restrictive (e.g., the repetition contingency; data not shown). Taken together, the present findings are in accordance with the proposal of Gharib et al. (2004) that variability (and we can assume stability too) is a function of the benefit/cost ratio of varying over repeating: When the benefits for varying are high, as when it increases the probability of new behaviors to be selected by changing contingencies (i.e., learning), variability tends to increase. However, when varying leads to reinforcement loss, as for example, when the actual contingency requires repetition, variability becomes less probable.

Final Considerations

The present experiments replicate findings obtained in studies that aimed to evaluate the effects of no-

reinforcement or variation-independent reinforcement conditions on operant variability, and vice versa. The major contribution of the present study is that all these independent and dependent variables were examined with the same procedure and with humans as participants. Previously, the majority of studies investigated only one or two of those variables with nonhuman subjects. A novel contribution of the present article was the broader assessment of historical effects on both variation and repetition learning. Maes (2003) found that preexposure to no reinforcement impaired variability learning, and he suggested that this might be a case of learned helplessness. We further examined this possibility by comparing the effects of preexposure to two types of no-contingent relations on the acquisition of operant variation and repetition. This manipulation allowed the learned helplessness hypothesis to be tested under another set of conditions and provided evidence that the no-reinforcement impairment may be influenced by other factors. Moreover, our results showed that inducing variability in a prior condition did not favor learning of a repetition sequence. These findings replicate the results of a study by Maes and van der Goot (2006) and suggest that more research is needed to elucidate whether variability can favor repetition learning with humans. Finally, the multiple assessment of induced and operant variability determinants across our experimental phases offer clear-cut evidence that variability levels were different in some measures (MetVar and systematic responding), but not in others (U value), across operant and inducing conditions. This might help in establishing a clearer distinction between these two types of behavioral variation. Of course, the present study also had shortcomings, such as the use of between-subjects comparisons and the limited number of disruptive operations. Despite these limitations, the present findings help clarify some variables affecting the acquisition of operant variation, the distinction between induced and operant variability, and, more generally, behavioral change and maintenance in accordance with the past and current contingencies of reinforcement.

AUTHOR NOTE

This article is derived from a doctoral dissertation submitted by the first author to the Universidade de Brasília. This work was conducted under the guidance of J.A.-R. and was supported by a scholarship provided to the first author by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). Portions of these data were presented at the 32nd Annual Meeting of the Association for Behavior Analysis (Atlanta, 2006), the XV Encontro da Associação Brasileira de Psicoterapia e Medicina Comportamental (Brasília, 2006), and the XXXVII Reunião Anual da Sociedade Brasileira de Psicologia (Florianópolis, 2007). The authors thank Fernando Rocha for developing the computer software, our lab group (Júnnia Moreira, Pablo Cardoso, Juliana Vilela, Andréia Kroger, Virginia Fava, and Roberta Ladislau) for their help in collecting portions of the data, and two anonymous reviewers and the editor for the helpful comments on earlier versions of the manuscript. Correspondence concerning this article should be addressed to A. Souza, Universität Zürich, Psychologisches Institut, Allgemeine Psychologie (Kognition), Binzmühlestrasse 14/22, CH-8050 Zürich, Switzerland (e-mail: a.souza@psychologie.uzh.ch).

REFERENCES

- ABRAMSON, L. Y., SELIGMAN, M. E. P., & TEASDALE, J. D. (1978). Learned helplessness in humans: Critique and reformulation. *Journal of Abnormal Psychology, 87*, 49-74.
- ABREU-RODRIGUES, J., HANNA, E. S., CRUZ, A. P. M., MATOS, R., & DELABRIDA, Z. (2004). Differential effects of midazolam and pentyl-enetetrazole on behavioral repetition and variation. *Behavioural Pharmacology, 15*, 535-543.
- ABREU-RODRIGUES, J., LATTAL, K. A., SANTOS, C. V., & MATOS, R. A. (2005). Variation, repetition, and choice. *Journal of the Experimental Analysis of Behavior, 83*, 147-168. doi:10.1901/jeab.2005.33-03
- ANTONITIS, J. J. (1951). Response variability in the white rat during conditioning, extinction, and reconditioning. *Journal of Experimental Psychology, 42*, 273-281.
- DENNEY, J., & NEURINGER, A. (1998). Behavioral variability is controlled by discriminative stimuli. *Animal Learning & Behavior, 26*, 154-162.
- ECKERMAN, D. A., & VREELAND, R. (1973). Response variability for humans receiving continuous, intermittent, or no positive experimenter feedback. *Bulletin of the Psychonomic Society, 2*, 297-299.
- GHARIB, A., GADE, C., & ROBERTS, S. (2004). Control of variation by reward probability. *Journal of Experimental Psychology: Animal Behavior Processes, 30*, 271-282. doi:10.1037/0097-7403.30.4.271
- GRUNOW, A., & NEURINGER, A. (2002). Learning to vary and varying to learn. *Psychonomic Bulletin & Review, 9*, 250-258.
- HUNZIKER, M. H. L., YAMADA, M. T., MANFRÉ, F. N., & AZEVEDO, E. F. (2006). Variabilidade e repetição operantes aprendidas após estímulos aversivos incontroláveis. [Operant variability and repetition learned after uncontrollable aversive stimuli]. *Psicologia: Teoria e Pesquisa, 22*, 347-354. doi:10.1590/S0102-37722006000300012
- LATTAL, K. A., & NEEF, N. A. (1996). Recent reinforcement schedule research and applied behavior analysis. *Journal of Applied Behavior Analysis, 29*, 213-230. doi:10.1901/jaba.1996.29-213
- MACHADO, A. (1989). Operant conditioning of behavioral variability using a percentile reinforcement schedule. *Journal of the Experimental Analysis of Behavior, 52*, 155-166. doi:10.1901/jeab.1989.52-155
- MAES, J. H. R. (2003). Response stability and variability induced in humans by different feedback contingencies. *Learning & Behavior, 31*, 332-348.
- MAES, J. H. R., & VAN DER GOOT, M. (2006). Human operant learning under concurrent reinforcement of response variability. *Learning & Motivation, 37*, 79-92. doi:10.1016/j.lmot.2005.03.003
- MILLER, G. A., & FRICK, F. C. (1949). Statistical behavioristics and sequences of responses. *Psychological Review, 56*, 311-324.
- MORGAN, D. L., & LEE, K. (1996). Extinction-induced response variability in humans. *Psychological Record, 46*, 145-159.
- NEURINGER, A. (1970). Superstitious key pecking after three peck-produced reinforcements. *Journal of the Experimental Analysis of Behavior, 13*, 127-134. doi:10.1901/jeab.1970.13-127
- NEURINGER, A. (1991). Operant variability and repetition as functions of interresponse time. *Journal of Experimental Psychology: Animal Behavior Processes, 17*, 3-12.
- NEURINGER, A. (1993). Reinforced variation and selection. *Animal Learning & Behavior, 21*, 83-91.
- NEURINGER, A. (2002). Operant variability: Evidence, functions, and theory. *Psychonomic Bulletin & Review, 9*, 672-705.
- NEURINGER, A. (2003). Creativity and reinforced variability. In K. A. Lattal & P. N. Chase (Eds.), *Behavior theory and philosophy* (pp. 323-338). New York: Kluwer/Plenum.
- NEURINGER, A. (2004). Reinforced variability in animals and people. *American Psychologist, 59*, 891-906. doi:10.1037/0003-066x.59.9.891.
- NEURINGER, A., DEISS, C., & OLSON, G. (2000). Reinforced variability and operant learning. *Journal of Experimental Psychology: Animal Behavior Processes, 26*, 98-111. doi:10.1037//0097-7403.26.1.98
- NEURINGER, A., KORNELL, N., & OLUFS, M. (2001). Stability and variability in extinction. *Journal of Experimental Psychology: Animal Behavior Processes, 27*, 79-94. doi:10.1037//0097-7403.27.1.79
- ODUM, A. L., WARD, R. D., BARNES, C. A., & BURKE, K. A. (2006). The effects of delayed reinforcement on variability and repetition of re-

- sponse sequences. *Journal of the Experimental Analysis of Behavior*, **86**, 159-179. doi:10.1901/jeab.2006.58-05
- ONO, K. (1987). Superstitious behavior in humans. *Journal of the Experimental Analysis of Behavior*, **47**, 261-271. doi:10.1901/jeab.1987.47-261
- PAGE, S., & NEURINGER, A. (1985). Variability is an operant. *Journal of Experimental Psychology: Animal Behavior Processes*, **11**, 429-452.
- SALDANA, R. L., & NEURINGER, A. (1998). Is instrumental variability abnormally high in children exhibiting ADHD and aggressive behavior? *Behavioural Brain Research*, **94**, 51-59. doi:10.1016/S0166-4328(97)00169-1
- SCHWARTZ, B. (1980). Development of complex, stereotyped behavior in pigeons. *Journal of the Experimental Analysis of Behavior*, **33**, 153-166. doi:10.1901/jeab.1980.33-153
- SCHWARTZ, B. (1982). Reinforcement-induced behavioral stereotypy: How not to teach people to discover rules. *Journal of Experimental Psychology: General*, **111**, 23-59.
- SKINNER, B. F. (1948). Superstition in the pigeon. *Journal of Experimental Psychology*, **38**, 168-172.
- STOKES, P. D. (1995). Learned variability. *Animal Learning & Behavior*, **23**, 164-176.
- STOKES, P. D. (1999). Learned variability levels: Implications for creativity. *Creativity Research Journal*, **12**, 37-45.
- TATHAM, T. A., WANCHISEN, B. A., & HINELINE, P. N. (1993). Effects of fixed and variable ratios on human behavioral variability. *Journal of the Experimental Analysis of Behavior*, **59**, 349-359. doi:10.1901/jeab.1993.59-349.
- WAGNER, K., & NEURINGER, A. (2006). Operant variability when reinforcement is delayed. *Learning & Behavior*, **34**, 111-123.
- WANCHISEN, B. A., & TATHAM, T. A. (1991). Behavioral history: A promising challenge in explaining and controlling human operant behaviour. *Behavior Analyst*, **14**, 139-144.
- WARD, R. D., BAILEY, E. M., & ODUM, A. L. (2006). Effects of *d*-amphetamine and ethanol on variable and repetitive key-peck sequences in pigeons. *Journal of the Experimental Analysis of Behavior*, **86**, 285-305. doi:10.1901/jeab.2006.17-06
- WARD, R. D., KYNASTON, A. D., BAILEY, E. M., & ODUM, A. L. (2008). Discriminative control of variability: Effects of successive stimulus reversals. *Behavioural Processes*, **78**, 17-24. doi:10.1016/j.beproc.2007.11.007

(Manuscript received February 19, 2010;
revision accepted for publication May 7, 2010.)