Interpretations for Reinforced Behavioral Variability: A Comparative Systematization

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Abstract: Experimental studies in Behavior Analysis have consistently demonstrated the effect of reinforcement contingencies on the increase in behavioral variability in nonhumans and humans. Despite their regularity and generality, the data presented in the literature have given rise to a variety of interpretations, leading to controversies over how to account for reinforced behavioral variability. The present study systematized the literature about variability with the aim of identifying and characterizing these interpretations, their underpinnings, and the criticisms directed at them. We identified interpretations involving the notion of variation as an operant behavior or, at least, as an operant dimension of behavior, and interpretations that dismissed this notion in characterizing the increase in variability as a secondary effect of behavioral processes present in variation contingencies. Not all interpretations found were based on established empirical bases, and only some were commented on or criticized by authors in the area.

Keywords: Behavioral Variability; Theory; Operant; Reinforcement; Behavior Analysis

Skinner, in all his works, and especially in proposing the causal model of selection by consequences (Skinner, 1981), highlighted the importance of studying behavioral variability as a characteristic of behavior (Sério et al., 2005). Behavioral variability was researched as a dependent variable in different experiments, which showed how it is affected by different independent variables. This became known in the literature as induced variability, obtained by exposing an organism to changes in variables such as extinction (e.g., Antonitis, 1951), reinforcer deprivation, reinforcer magnitude (e.g., Carlton, 1962), intermittent reinforcement schedules (e.g., Boren et al., 1978; Eckerman & Lanson, 1969), and the administration of different drugs (e.g., Moerschbaecher et al., 1979).

Behavioral variability obtained by reinforcement contingent to variation became known in the literature as reinforced variability (see review by Neuringer, 2002). The increase in variability by way of reinforcement was consistently replicated in different species of subjects, topographies, and dimensions of the target response, behavioral units, settings, types of reinforcers, and procedures for the reinforcement of variability, with studies using several different variability measures. Furthermore, the successful increase of behavioral variability by way of reinforcement has been documented in applied settings with human participants with typical (e.g., Goetz & Baer, 1973; Maloney & Hopkins, 1973; Ryan & Winston, 1978) and atypical development (see review by Silbaugh et al., 2021).

Despite the regularity and generality of the obtained data, there are disagreements as to how to interpret these results. For some authors, these contingencies directly reinforce variability, which is considered to be an operant dimension (Doughty & Galizio, 2015; Neuringer, 2002, 2003, 2004, 2009, 2012; Neuringer & Jensen, 2010, 2012, 2013; Page & Neuringer, 1985; Rodriguez & Thompson, 2015), and for others the resulting variability is a byproduct of the programmed reinforcement contingencies in the studies and not directly reinforced (Barba, 2015; Holth, 2012a, 2012b, 2016; Machado, 1989,

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1992, 1997; Machado & Tonneau, 2012; Nergaard & Holth, 2020). In addition, there is a wide range of interpretations within these two large groups that feed the debate in the scientific community.

Different interpretations for reinforced variability raise theoretical issues that still need to be addressed concerning the behavioral processes involved in the phenomenon. To be compatible with radical behaviorism's approach to the production of knowledge, these answers depend on both the production and the interpretation of new experimental data:

> A theoretical construction may yield greater generality than any assemblage of facts. … It [theory] will not stand in the way of our search for functional relations because it will arise only after relevant variables have been found and studied. (Skinner, 1950, p. 216)

For Skinner (1950), theoretical concepts about behavior and its properties should be based on data or, in other words, on the control of the researcher's verbal behavior by the object of study. On the other hand, Skinner (1950) is clear in stating that a "collection of uniform relationships" is insufficient since theories are not facts in themselves but rather the effect of these facts on the scientist's verbal behavior. There are several examples in the literature showing that the same data can evoke different interpretations, as in the case of the observed fact that there is response suppression after punishment —which is expressed in the symmetrical and asymmetrical definitions of punishment (Holth, 2005).

Based on these considerations, a comparative systematization of different existing interpretations for variability can allow us to identify their constituent components, empirical bases, weaknesses, as well as their implications for the development of this research field in behavior analysis. This exercise can foster empirical research that could transform these interpretations and their effectiveness in increasing the prediction and control of behavior.

The aim of the current article is to present different interpretations for reinforced variability found in the Behavior Analysis literature, as well as the foundations for each and the criticisms directed at them.

We analyzed theorical and literature review articles about behavioral variability, in addition to the Introduction and Discussion sections for experimental reports that discussed interpretations for reinforced variability.

Initially, we read articles authored or co-authored by Neuringer, one of the main researchers in behavioral variability. This material was collected from a list of publications in the researcher's profile on *Research Gate*, which contained 83 texts. Of these, two were discarded as repetitions, and 43 for not dealing with the topic of "variability," which was determined by reading the titles, abstracts, and keywords of each article. Of the 38 remaining texts, 28 were not analyzed due to being research reports already discussed in the remaining 10 theoretical and literature review articles written by the author. Two of these 10 articles did not deal with the author's interpretation for variability (which was confirmed by reading all 10 in their entirety). As a result, eight articles by Neuringer were selected for analysis (indicated by a single asterisk in the reference list).

New searches with the term "Neuringer, Allen" on *PsychInfo*, *Portal de Periódicos CAPES*, and *Google Scholar* did not produce new articles. Following this, we read six more articles, from other authors, which were published in a special 2012 issue of the journal *The Behavior Analyst* about behavioral variability, indicated by two asterisks in the reference list.

In a later stage, new articles were included to this list based on our previous knowledge and on the references cited by the authors of the selected texts when presenting or discussing interpretations for reinforced variability. These were both theoretical texts and experiment reports about the topic. As a result, over 16 articles were included, indicated in the reference list by three asterisks, totaling 30 texts that were analyzed.

We read each text in its entirety and recorded the authors' interpretations for reinforced variability, as well as the criticisms directed at any of the other existing interpretations. We also noted any descriptions of empirical bases presented to support the interpretations and/or criticisms.

Based on this systematization of the material, we identified that one group of interpretations for reinforced variability revolves around the premise that variability is an operant dimension of behavior directly affected by reinforcement. A second group, on the other hand, shares the notion that the increase in variability (when reinforcement is made contingent to certain variation criteria) does not mean that variation is an operant dimension but rather a secondary effect of other behavioral changes produced

by reinforcement. We initially considered the existing debate between these two wider groups of interpretations for reinforced variability.

Among the interpretations in the first group, we will present (1) the tripartite theory defended by Neuringer; (2) reinforced variability as a generalized operant; and (3) reinforced variability as an operant variation between patterns of switching and repeating.

From the second group, we will present the interpretations of variability as a byproduct of (1) the reinforcement of switching; (2) negative frequency-dependent selection; (3) the absence of consistent selection with the balance hypothesis; and (4) of a dynamic process of intermittent conditioning and extinction of responses or response patterns.

When possible, we will highlight the complementary or opposing relationship between existing interpretations according to their proponents or commentators from the behavior analysis community.

Variability as an operant versus variability as a secondary effect of other processes

Some of the interpretations in the literature about the variability observed under variation contingencies involve the idea that "varying" is an operant behavior reinforced in these circumstances (Doughty & Galizio, 2015; Neuringer, 2002, 2003, 2004, 2009, 2012; Neuringer & Jensen, 2010, 2012, 2013; Page & Neuringer, 1985; Rodriguez & Thompson, 2015). Another version claims that variability is a dimension of any operant behavior and that it is directly reinforceable—just like topography, duration, force, latency, response rate, etc. (Neuringer, 2002).

Neuringer (2002) presented the following experimental data to defend the perspective that reinforced variability should be considered operant: (a) yoked schedules demonstrated that the reinforcement contingency for varying, and not the mere intermittence of reinforcement, is responsible for the increase in variability (e.g., Page & Neuringer, 1985); (b) studies showed that variability, as well as other dimensions of operant behavior, can be placed under discriminative control (e.g., Cohen et al., 1990; Denney & Neuringer, 1998; Page & Neuringer, 1985); (c) different variation requirements for reinforcement resulted in corresponding levels of variability (e.g., Page & Neuringer, 1985); and (d) choices between varying and repeating in concurrent schedules were a function of the probability of reinforcement, just as with any operant in choice procedures (e.g., Abreu-Rodrigues et al., 2005; Neuringer et al., 2000).

There are, however, authors who argued that even if variability could be considered a dimension of behavior, it would not be a first-order dimension (such as topography, duration, force, location, and interresponse time), but rather a second-order dimension since it refers to these other dimensions (Machado & Tonneau, 2012; Pennypacker, 2001). The very notion that varying is an operant is not a consensus (Barba, 2012a, 2012b, 2015; Holth, 2012a, 2012b, 2016; Machado, 1989, 1992, 1997; Nergaard & Holth, 2020), being the target of theoretical, methodological, and empirical criticisms.

Some authors even discussed the criteria used to determine whether a behavior is operant (Barba, 2012a, 2012b; Holth, 2012a; Marr, 2012; Palmer, 2012). Barba (2010, 2012a, 2012b), for example, conceded that reinforced variability could be operant, but argued that the necessary and sufficient conditions for this statement to be adopted by the behavior-analytic community have not yet been shown. Based on the definition of operant given by Catania (1973, 1998), Barba (2012a) wove methodological criticisms into the studies in this field that, according to him, still had not demonstrated a condition that is necessary (but, also according to him, possibility not sufficient) to determine whether varying is actually an operant behavior: the correspondence between the measured response property (functional class) and the response property programmed to be reinforced by the contingency (descriptive class). The core of these criticisms is the fact that the measure used by studies in the field (usually the U value) does not correspond to the criteria used for reinforcement in variability reinforcement procedures, meaning there is no way of assessing the continuity between the reinforced behavioral properties and the properties whose distribution should indicate a response differentiation, allowing us to determine if we are dealing with an operant as defined by Catania (1973, 1998).

Barba (2006, 2012a, 2012b) also highlighted the need to define what is being called variation in these studies, to describe what measures are being used, and to adopt a more parsimonious position in studying the susceptibility of each of these measures to reinforcement rather than simply assuming they are different measures of the same phenomenon labeled "variability." A similar issue was discussed by Nergaard and Holth (2020) regarding the analysis procedures for variability measures obtained in

studies: since several of the more common analyses involved aggregated statistics and the use of molar analyses, both the behavioral units reinforced in procedures as well as the units that were not reinforced or did not constitute functional units were grouped into the phenomenon of variability. In these cases, the class described by the researcher did not necessarily coincide with the class established by reinforcement. This observation let the authors defend the use of molecular analysis (i.e., moment-to-moment) of the experimental subject's behavior. Shimp (2014) also discussed the suitability of molar and molecular analyses in the study of behavioral variability.

Nergaard and Holth (2020) presented further criticisms derived from those cited above. The first concerns the fact that most basic research studies about reinforced variability expose the organism to a variability contingency without the previous establishment of the behavioral units within which said organism should vary. This methodological decision implies a mixture between the reinforcement of variability and the reinforcement of the units themselves. We could add that this also limits our ability to compare basic research to applied studies, in which units are directly trained prior to variability reinforcement or, at least, could be assumed to be part of the individual's pre-existing behavioral repertoire. In the basic research literature, we identified some studies that established different functional classes prior to reinforcing variability, specifically different durations of nose-poking (Duarte et al., 2005) and lever-presses (Cruvinel & Sério, 2008).

Nergaard and Holth's (2020) second criticism refers to the difficulty of comparing procedures used to reinforce variability to those in other behavioral-analytic studies of different phenomena that demonstrated the repetition of a behavior as a result of its reinforcement. As emphasized by these authors, traditional studies about operant behavior prioritize free-operant procedures rather than discrete trials, a methodological contribution to the study of behavior that characterized Behavior Analysis (Skinner, 1953/1965). The first variability studies, however, just as those of today, started using discrete trial procedures, imposing intervals between responses, between trials, and using timeouts after sequences considered to be repetitions. Regarding this, the authors argued that the effects of each of these characteristics must be understood rather than assumed not to interfere with the subject's responding, which has been evidenced in studies that investigated the effects of free-operant procedures and discrete trials on behavioral variability (Giolo, 2010; Micheletto et al., 2010; Morris, 1987).

An empirical issue raised by Nergaard and Holth (2020), which would justify greater parsimony when affirming that variability is an operant, came from experimental findings that showed opposite effects of the same variable on a repeated operant and on measures of variability. An example of these variables is reinforcer delay, which, in repetition contingencies, normally decreases the effect of the reinforcer in strengthening the operant at hand, made evident by the reduced frequency of this operant. In variability studies, in contrast, reinforcer delay increases—rather than decreases—measures of variability, which would lead one to believe that variability itself is not the operant the reinforcer is acting upon.

Alternatively, some authors (Barba, 2015; Holth, 2012a, 2012b, 2016; Machado, 1989, 1992, 1997; Machado & Tonneau, 2012; Nergaard & Holth, 2020), contrary to the idea of variability being an operant, discussed the phenomenon as a secondary effect relating to the effects of reinforcement on other behaviors or response dimensions. In other words, all the interpretations belonging to this group revolve around the common premise that what is being directly reinforced is not variability but rather other behaviors that, when strengthened or weakened (even in an inconsistent and temporary manner), are accompanied by greater levels of variability.

Interpretations of variability as an operant

There are different interpretations that could be grouped into the larger set of interpretations for variability as an operant or, at least, a dimension of operant behavior that is directly reinforceable. We will present them below.

Neuringer's tripartite theory. Considered the main author to defend the idea that variability is operant, Neuringer (2002) presented a theory with three interpretations for reinforced variability:

> Three processes are hypothesized to underlie operant variability. The first involves the use of random environmental events, such as the toss of a coin. The second involves memory for

responses, such as when an animal learns not to return to previously visited locations. The third will be referred to as an endogenous stochastic generator. (p. 690)

As we will see, sometimes these three interpretations are presented in articles as complementary, in that reinforced variability could originate from three different processes or that there could exist different types of reinforced variability; and at other times they are presented as mutually exclusive, such as when the author compared the interpretation for memory-based variability with the hypothesis of an endogenous random generator, stating that confirming the latter would depend on refuting the former.

The use of random environmental events. The first process Neuringer (2002) refers to, the use of random environmental events, is described as a method used by several cultures throughout history to influence choices and decisions in different contexts, such as in games, science, and art. An example of the production of behavioral variability based on random events was given by Neuringer (2004) when referring to the novel *The Dice Man*, in which a bored psychiatrist writes a variety of possible actions on pieces of paper, selects them at random, and acts accordingly.

In this example, the resulting behavioral variability could be attributed to the control exerted by deliberately randomized environmental events (words written on a piece of paper). In summarizing his "tripartite theory" for operant variability, Neuringer (2002) refers to that source of variability as "attention to random events in the environment" (p. 695), and states that these events would assure unpredictable responding. The randomization of these events could be produced either by the organism's responses (e.g., selecting slips of paper with a description of what to do and behaving accordingly) or by the accidental occurrence of events that control responding when there is reinforcement of variability, building upon chance (e.g., an accidental spray of paint on a canvas could control brush strokes that transform the spray into an unexpected image).

In the first texts we analyzed, Neuringer (2002, 2004) seldom explored this interpretation, and, in other articles, he never mentioned it at all (Neuringer, 2003, 2012, Neuringer & Jensen, 2010). Furthermore, we observed a change in the treatment and emphasis given to the topic over time. The author increasingly began to discuss random events alongside other processes used to explain induced variability. The topic lost its prominence as an explanation for reinforced variability, showing up only as a complementary process that induces variation to be reinforced in an operant manner. In Neuringer (2009), this interpretation is called "environmental accidents," under the subheading "non-contingent effects" (together with "decreased reinforcement" and "reinforcement uncertainty"). According to Neuringer (2009),

Accidents, decreased reinforcement, and reinforcer uncertainty are discussed as "non-contingent" effects because variability does not control these events. Non-contingent and contingent effects—the latter due to direct effects of reinforcing variability—often occur jointly, or interactively. (p. 328)

The interpretation of variability based on the use of random environmental events was not presented by Neuringer and Jensen (2012). However, similarly to what Neuringer (2009) called "environmental accidents," they presented the interpretation that "unrelated events within the environment or organism" (p. 57), together with extinction and other variables, could induce behavioral variability and be combined with a variability-reinforcement contingency.

Finally, Neuringer and Jensen (2013) referred to the interpretation of variability based on random events (using the same example as in Neuringer, 2002) in the subheading "noncontingent effects," considering it as an example, among others, of how "… random events that are independent of an individual's actions may be used to avoid biases, engender unlikely responses, and break out of behavioral ruts" (p. 522).

Both in the texts that presented the interpretation of reinforced variability being generated by random environmental events (Neuringer, 2002, 2004) and in those that presented this same idea as an interpretation for induced variability rather than reinforced variability (Neuringer, 2009; Neuringer & Jensen, 2012, 2013), the other two accounts belonging to the tripartite theory were contrasted and discussed with greater emphasis.

Another characteristic of the discussions concerning the interpretation for random environmental events is that it was only mentioned by Neuringer, out of all the analyzed texts, indicating it plays a secondary role in discussions in the field. Furthermore, Neuringer did not cite any empirical studies when commenting on the matter, suggesting the idea lacks, to this day, an experimental basis.

Memory-based variability. Another hypothesis created by Neuringer to explain variability generated by reinforcement is that of "memory" (Neuringer, 2002, 2003, 2004, 2012; Neuringer & Jensen, 2010, 2012, 2013). According to this interpretation, under contingencies that reinforce variation, an organism could alternate between responses or sequences, "basing their current response on memory for, or discriminative control by, the just emitted responses." (Neuringer, 2002, p. 690), at least concerning a recent past. In this same text, the author proposed that the contingency differentially reinforces "nonrepetitions."

Neuringer (2002, 2004) specified the type of controlling relations involved in what he termed "memory": it relates to the discriminative control of an organism's responses by recently emitted responses, which act as the antecedent stimuli. In other words, the author considers the possibility that the increase in variability is, at least in some cases, the product of discriminations involving the organism's own responding as an antecedent stimulus.

Neuringer (2002) exemplified situations in which variation is strengthened by "remembering": varying which students get called upon to answer questions in class, varying locations in which we search for a hidden object or trying different approaches to solving a problem. The author also added that external cues, such as messages to oneself and scientific records, help to increase "memory capacities" (p.695).

Regarding the patterns generated by variation contingencies that could be related to the interpretation of memory-based variability, Neuringer and Jensen (2010, 2012, 2013) contrasted response patterns they called stochastic or random to the type of responding they termed chaotic.

Despite using the expressions "stochastic responding" and "random-like behavior" interchangeably, the authors indicated that the term "random" refers to maximum levels of unpredictability or equiprobability between response alternatives, while the term "stochastic" would be more appropriate for patterns considered to be probabilistic but not equiprobable.

On the other hand, Neuringer and Jensen (2010, 2012, 2013) and Neuringer (2012) used the terms "chaotic" or "strategic" to refer to apparently unpredictable patterns. These are difficult to differentiate from stochastic patterns, but, in a nonlinear manner, they present some degree of order in that an event is controlled by past events. The authors related this pattern to memory-based variability.

The interpretation of memory-based variability appeared in all texts by Neuringer that we analyzed, even though it was sometimes described with different emphases in each stage of development of this author's work. Generally, the idea was presented as one possible interpretation, but which did not explain all the cases involving an increase in behavioral variability by reinforcement, leading to the premise of a random generator as an alternative (Neuringer, 2002, 2003, 2004, 2009, 2012; Neuringer & Jensen, 2010, 2012, 2013).

An experimental investigation of both the memory and quasi-random hypotheses for reinforced variability can be seen in the work of Page and Neuringer (1985, Exp. 4), with the manipulation of the size of the response sequence used as the unit for the reinforcement of variability. The conclusion of this experiment—and of many others (Abreu-Rodrigues, et al., 2004; Cohen et al., 1990; Machado, 1993; Manabe et al., 1997; McElroy & Neuringer, 1990; Morris, 1987; Neuringer, 1991) mentioned by Neuringer (2002) in discussing this hypothesis—is that the empirical findings are inconsistent with the interpretation of memory or, at least, with the interpretation that memory generates response patterns considered to be random or stochastic, suggesting the possibility that, in rare cases, memory could explain patterns labeled as strategic or chaotic. According to Neuringer (2002), this hypothesis would better explain some specific cases of reinforced variability in which there is greater response predictability, especially under lenient variability contingencies: "one strategy that subjects can employ is to cycle through few responses or sequences, especially when the variability contingencies are relatively permissive" (p.690).

Neuringer (2009) and Neuringer and Jensen (2010) further discussed whether memory limits (rather than facilitates) variability or if it occupies an ancillary role in explaining the phenomenon. This discussion revolved around a statement by Weiss (1965) about how a lack of memory of prior responses

is necessary for random responding, to which Neuringer and Jensen (2010) argued that "the results [of the experimental literature presented by the authors] were clearly inconsistent with a memory hypothesis to account for operant variability" (p.980). In a later text, Neuringer and Jensen (2012) considered the possibility that random variability and memory-based variability are complementary:

> With respect to operant variability, there is support for both deterministic and indeterministic processes playing a role, often in conjunction with one another. In some cases, generation of highly variable responses relies chiefly on memory for past events. In others, the evidence is consistent with a primarily stochastic process. (Jensen & Neuringer, 2012, p. 69)

A similar position can be seen in Neuringer and Jensen (2013), but in this case the authors, commenting on the experimental studies by Machado (1993), who manipulated the size of response sequences, and by Manabe et al. (1997), who manipulated the requirements for a lag n schedule, suggested that memory-based variability occurs in some cases, when possible, but not when there are high memory demands. In these studies, the variability obtained with sequences of one or two responses in one experiment and with lag 1 and lag 2 in the other, respectively, was interpreted by Neuringer and Jensen (2013) as memory-based, which was not the same case for the variability obtained with sequences of three or more responses or with lag 3. Neuringer and Jensen (2013) concluded that:

> under recency and frequency-based methods of variability reinforcement, variable responses are generated via memorial processes when possible, but reversion to stochastic-like emission is seen when memory requirements exceed the organism's capacity. (p.527)

Within the three interpretations proposed in Neuringer's tripartite theory, the memory-based interpretation is the only one for which he provided a description of empirical studies that tested its validity. Testing this hypothesis, according to author, would determine to what extent the random generator hypothesis could be accepted. As a methodological strategy to empirically test the memory hypothesis and produce the necessary evidence, Neuringer and Jensen (2012) suggested investigating the effects of interposing interfering events between the controlling past event and the response in question:

> A memory-based response, by definition, depends upon control by prior events, either stimuli or responses, and if an interfering event is interposed between the controlling event and the behavior in question, then memory might be degraded and the outcome suffer. On the other hand, stochastically generated outcomes do not depend upon (nor can they be predicted with knowledge of) prior stimuli or responses and thus interfering events should not affect stochastic outputs. In short, if an interfering event degrades operantly reinforced variations, then that provides evidence consistent with a memory and against a stochastic Generation process. Absence of memory interference provides evidence consistent with stochastic generation. In cases where interference produces a partial reduction in operant variation, it is reasonable to assume that both play a role. (p.72)

Different independent variables have been manipulated as interfering events to evaluate the pertinence of the memory hypothesis for behavioral variability (see Neuringer, 2002). Most of the results of these investigations (some produced later than the texts analyzed in the current study) showed that the levels of variability are larger under conditions in which remembering one's own past behavior is supposedly more difficult or prevented by different interfering events, such as (a) an increase in the schedule requirement for reinforced variability (Manabe, et al., 1997; Page & Neuringer, 1985); (b) an increase in the size of the sequence used as the behavioral unit (Machado, 1993; Page & Neuringer, 1985); (c) and increase in the size of the interresponse interval (called IRT in some studies and IRI in others) within the behavioral unit (Bitondi, 2012; Doughty & Galizio, 2015; Morris, 1987; Neuringer, 1991); and (d) exposure to drugs that interfere with discriminative control (Abreu-Rodrigues et al., 2004; Cohen et al., 1990; McElroy & Neuringer, 1990).

However, there are objections to Neuringer's interpretation of the data. The most general objection, pointed out by Doughty and Galizio (2015), is that the interference of these variables on memory is inferred rather than directly demonstrated. There is an assumption that the manipulated variables

interfere with the stimulus control that would be involved in memory-based variability, but there is no direct measurement of the presence or lack of this control by past responding—merely the direct measurement of variability itself, which is supposedly related to memory.

Studies by Doughty and Galizio (2015), with pigeons, and by Leite (2021), with humans, assessed whether discriminated control by previous responding, established by matching to sample (MTS) procedures, would interfere with behavioral variability under threshold contingencies. All three authors indicated that accurate control of past responding in the MTS task did not affect variability.

Differently to what happened with the interpretation of variability based on random events, the interpretation of memory-based variability was largely commented on by other authors in the field (Barba, 2015; Doughty & Galizio, 2015; Holth, 2012a, 2016; Machado, 1992, 1997; Machado & Tonneau, 2012; Marr, 2012; Nergaard & Holth, 2020). Furthermore, it presented implications for other interpretations discussed by these authors.

Endogenous stochastic generator. The third interpretation suggested by Neuringer (2002) for the increase in behavioral variability by reinforcement is called the random hypothesis or quasi-random hypothesis. According to this interpretation, referred to by the author himself as the "most controversial" (p.695), the organism emits each response in a sequence as a random event, and this would be related to an innate mechanism for variation. Page and Neuringer (1985) called this a "variability generator": an innate mechanism that would be activated by environmental contingencies requiring variation for reinforcement to occur. The authors suggested that this generator would be a source of behavioral variability over which reinforcement contingencies would assume control. Doughty and Galizio (2015) refer to this as the endogenous-random-generator (ERG) hypothesis. The following excerpt revives Neuringer's (2002) presentation of this hypothesis:

> Operant conditioning of new responses may depend on stochastic variations. It is impossible to prove stochasticity; some presently unknown deterministic system may ultimately explain the results. However, the evidence is consistent with the stochastic hypothesis and inconsistent with the alternatives. For example, memory is not sufficiently powerful to explain all operant variability, memory-interference procedures leave stochastic responding intact, and behaviors correlate well with those of stochastic models. (p. 695)

Another element involved in ERG refers to the explanation of why organisms repeat reinforced behaviors in contingencies that do not require variability. According to Page and Neuringer (1985),

> It is advantageous for an animal to discriminate situations in which new responses must be learned from those in which previously learned behaviors must be repeated. We hypothesize that this discrimination is based on the reinforcement of diverse responses and response classes in the former case versus reinforcement of fixed, or stereotyped, responses and response classes in the latter. ... Turning on or off a variability generator may be under the control of reinforcement, but the variability generator is not itself created through reinforcement. An animal may be born with the variability generator intact. (p.449-450)

As Neuringer (2002) himself stated in the cited passages, considering the very nature of the proposed interpretation, there is little or no positive evidence to confirm it. Many of the presented arguments for the existence of an ERG are based on the previously mentioned data, which, according to him, challenge the memory hypothesis. A more extensive and accurate experimental analysis of the memory hypothesis is fundamental, therefore, since the ERG hypothesis proposed by Neuringer is based on possible failures or gaps in this other interpretation. Still, it is relevant to note that questions surrounding his hypothesis are based on issues surrounding a separate account, since refuting the memory hypothesis with new findings does not automatically prove the random hypothesis.

Neuringer (2002), to strengthen the random hypothesis, argued that the distribution of the subject's responses in some studies (e.g., Neuringer, 1986; Page & Neuringer, 1985) conforms to what is obtained by a random computer generator, and that changes in variation requirements in the reinforcement schedules affect variability in real subjects just as with computers. These data, however, as Neuringer (2002) highlighted, are merely correlational, in the sense that changes in variability were observed to occur simultaneously both in the computer's random generator and in the behavior of live organisms. In addition, the strategy of comparing the performance of live organisms to the results of a computer

simulation could be questioned due to inducing cognitivist explanations for the observed changes in the behavior of the real experimental subjects, suggesting similarities between information processing in a computer program and behavioral processes responsible for the subject's responding, which merits further discussion. Skinner's (1977) criticism of comparing human behavior to the functioning of machines is rather emphatic: "The struggle to make machines that think like people has had the effect of supporting theories in which people think like machines" (p.7).

Aside from being recognized by Neuringer (2002) as an interpretation that is difficult to prove or refute, the idea of an endogenous random generator has received criticism, both theoretical and epistemological, from other authors (Machado & Tonneau, 2012; Marr, 2012). Marr (2012) highlighted this formulation's mentalistic character and how it lacks predictive value:

> … Neuringer's (2002, 2004) proposed ''endogenous stochastic generator'' may be a misnomer, but in my view that is the least of its problems. This appears to be a ''mechanism'' as name, in the tradition of Chomsky's ''language acquisition device,'' an invention with just the properties needed to explain the findings, but with little, if any, predictive power. At best, empirical findings are said to be ''consistent'' with the notion. What turns such a generator on or off? How does the operation of such a generator lead to behavior? Where is it located? Is there an ''endogenous deterministic generator'' as well? (pp. 240-241)

Machado and Tonneau (2012) criticized the assumption made by Page and Neuringer (1985) that there is a difference between the contingencies of variation and those of repetition that "activate" ERG, and that a similar discrimination occurs between different levels or requirements for variability to explain higher levels of variability under more demanding contingencies:

> ... the account suggests (probably metaphorically) that animals ''turn on'' a random generator When they ''discriminate'' that reinforcement follows diverse responses. But consider a Lag 5 contingency. It seems odd that an animal capable of detecting that reinforcement follows ''diverse responses'' would generate as many as 30 different sequences in a 50-trial session when only six sequences, cycled through systematically, would suffice to obtain all available reinforcers (see Page & Neuringer, 1985, Figure 6). Arguing that memory limitations prevent the animal from cycling through the six sequences systematically is questionable because the initial discrimination implies no such limitations. More generally, the account grants pigeons significant memory powers to discriminate a high level of sequence variability (and tune the variability generator accordingly), but then denies them the same memory powers to vary a few sequences systematically. The account is, if not contradictory, at least implausible. (p. 253)

Concerning the criticism cited above, made by Machado and Tonneau, there are experimental data showing the discriminative control of behavior in schedules with multiple variation and repetition components (e.g., Page & Neuringer, 1985, Exp. 6). At the same time, there are data indicating the possibility of placing a pigeon's responding in MTS tasks under the conditional discriminative control of variation and repetition reinforcement contingencies (Souza, 2006). However, this depends on the discriminability between these two contingencies, with conditional discrimination becoming less accurate as the variability schedule becomes more lenient. At least in part, these data show that subjects can be brought under discriminative control even under conditions in which "reinforcement follows several 'diverse responses'" (Machado & Tonneau, 2012, p. 253) or repeated responses, while also suggesting there are limits to this type of discrimination.

Despite the criticisms garnered by the notion of an endogenous random generator, in the texts by Neuringer that we analyzed, we noted that this was the interpretation he defended most (Neuringer, 2002, 2003, 2004, 2009, 2012; Neuringer & Jensen, 2010, 2012, 2013), even though his treatment of the idea changed throughout the years. As previously shown, it was Page and Neuringer (1985) who first introduced the notion of an innate generator. But the term "endogenous" was only used in Neuringer (2002, 2004) to describe an innate random generator as a source of variation, but not in other articles (Neuringer, 2003, 2009, 2012, Neuringer & Jensen, 2010, 2012, 2013). In Neuringer (2002, 2009), the term "endogenous" also appeared in an explanation for a type of variability that is not reinforced and that is different to induction by noncontingent events: "Some variations are due to eliciting (or noncontingent) influences, some to selective or reinforcing influences, and some to

endogenous effects" (Neuringer, 2009, p.335). The author did not clarify, however, what these endogenous effects would be and how they would act upon behavioral variability.

Use of the term "generator" also changed over time. Neuringer (2002, 2004) referred to the "endogenous stochastic generator"; and Neuringer (2003, 2009), to the "stochastic generator" or "random generator." The author used "stochastic" more frequently, except when naming the data analysis procedure used to compare the performance of experimental subjects with the output of a computer program that generated random sequences. Neuringer (2012) used the term "generator" merely to describe the data analysis procedure and left it out of his hypothesis, which came to be known solely as the "random hypothesis." Neuringer and Jensen (2010, 2012, 2013), however, at times still referred to this interpretation as the "random generator hypothesis" or the "random generator model," sometimes substituting "random" with "stochastic" and leaving out statements that characterized it as innate or endogenous.

Below we present other interpretations for reinforced variability as an operant behavior found in the literature, which are not necessarily incompatible with those put forth by Neuringer.

Varying as a generalized or higher order response class. Another interpretation for reinforced variability as an operant behavior proposes that "to vary" constitutes a "generalized skill" (Neuringer, 2002), a "generalized repertoire," or a "higher order class of behavior" (added by Rodriguez & Thompson, 2015). This is not incompatible with the other interpretations presented so far, and one could even argue that it does not represent a new interpretation for reinforced variability. However, it has been mentioned in the literature, and at times criticized, as an interpretation for reinforced variability (Doughty & Galizio, 2015; Marr, 2012). In Barba (2015), variability was compared to imitation in that both could be considered generalized operants:

> Neuringer (2012) identifies the operant "to vary" with other generalized operants like imitation. In imitation training each reinforcer follows a particular response (a response with particular topography). The training is successful, however, not if responses with particular topography become more likely but if responses with topographies similar to the model become more likely. That is, reinforcement does not affect an intrinsic response property (like its topography), but it affects, instead, a relational response property, namely, the similarity between response topography and the model (similarity is the response property upon which reinforcement is contingent). The generalized operant "to imitate" is then shaped. Similarly, in contingencies based on response frequency, each reinforcer follows a particular response sequence (a sequence with particular configuration). The generalized operant to vary is shaped, however, not if sequences with particular configuration become more likely but if sequences with configurations infrequent in the previous trials become more likely (infrequency is the sequence property upon which reinforcement is contingent). (p.98)

According to this interpretation, "an individual may be able to be taught "what it means to vary" independent of the characteristics of individual responses" (Rodriguez & Thompson, 2015, p.182). The authors argued that this ability would be useful in situations in which "trying something else" has a function, such as in shaping procedures, problem-solving, and extinction (when reinforcement for previously reinforced responses is interrupted). In these situations, stimuli correlated to suspension of reinforcement could, according to Rodriguez and Thompson (2015), function as discriminative stimuli for varying. A similar interpretation can be found in Shahan and Chase (2002), in which the authors suggested that, after a history of varied responses having led to solutions to problems, the very occurrence of situations with new problems could evoke greater behavioral variability.

Establishing variation as a higher order operant class would involve, still according to Rodriguez and Thompson (2015), training with a sufficient number of examples of stimulus-response relations, reinforcing varied responding in diverse stimulus conditions involving the sudden removal of reinforcement, different relevant responses and response dimensions (they cited the examples of frequency, duration, and intensity). The authors also suggested training this generalized repertoire by placing instances of generalized variance (occurring in different conditions to that of previous training) under contingent reinforcement.

When commenting on this interpretation, Doughty and Galizio (2015) highlighted that "repeating" could also be, from their point of view, a higher order class and that a possible interpretation is that

contingencies that require variability, such as those in Lag *n* and threshold schedules, for example, differentially reinforce the generalized behaviors of variation and repetition. Under such contingencies, the organism learns, over successive instances, that more periods of variation (e.g., between sequences of responses) are followed by reinforcers than periods of repetition (e.g., between sequences of responses). An open question concerning this interpretation is that, according to Doughty and Galizio (2015), it still does not indicate the appropriate unit of analysis for reinforced variability, allowing for multiple possibilities, such as the whole sequence of responses (i.e., between-sequence processes) and/or one or more responses (i.e., within-sequence processes). In raising this question about the unit at which variability is reinforced, Doughty and Galizio (2015) proposed another interpretation, which better describes the changes in within-sequence responses, which we will present later.

Marr (2012) and Holth (2012b) presented criticisms that also point to the imprecise definition of the functional unit established by reinforcement when appealing to the notion of a generalized operant. According to Marr (2012): The remarkably seductive and flexible concept of the ''generalized operant'' (a kind of ''super-unit'') seems infinitely extendable, making it difficult not to apply it, as needed, to account for virtually any behavior we deem fit" (p. 241). In Holth's (2012b) perspective:

> Conceptually, the idea of an operant class that consists of, or includes, all sorts of novel instances is problematic because such a class would have no defining criteria to permit the counting of instances, or even to specify Where an instance of novel behavior starts or ends. (p.88)

Holth (2012b) indicated that the problems with the premise that variation is a generalized operant are similar to those already debated in the field of stimulus control concerning the use of "relational responding" (from Relational Frame Theory - RFT) to explain equivalent stimulus class formation. For example, neither area of investigation has demonstrated clear experimental control of the emergence of the generalized class they claim to exist. Furthermore, Nergaard and Holth (2020) cited studies containing data that showed that the very possibility that reinforcement strengthens long sequences as units is, at the very least, controversial.

Despite these raised issues, the concept of variation as a generalized operant is useful, for example, in explaining high levels of variability in a new context, in which variability had not been reinforced, but that has properties in common with other contexts in which variability had been reinforced. This phenomenon has still not been explained by other interpretations that dismiss the notion of variation as an operant (Barba, 2015).

Following this logic, experimental studies that test the generalization of reinforced variability to other settings, for new tasks or even different dimensions of responding (e.g., Fialho et al., 2015; Kong et al., 2019; Parsonson & Baer, 1978) could help refine this interpretation—be it providing evidence of a generalized operant, be it providing data that reduces the phenomenon to more elementary behavioral processes, thus dismissing the premise of a higher-order operant.

Variation between switching and repeating. Another interpretation, briefly presented by Doughty and Galizio (2015), is that the increase in variability between sequences obtained by reinforcement is, in fact, a consequence of varying between behavioral patterns of within-sequence switching and repeating. This interpretation involves "switching" and "repeating" but maintains "varying" as an operant (differentiating it from the hypotheses described below, which do not consider variation to be an operant). Despite this, it does not assume that the organism learns to vary between response sequences when reinforcement is contingent to behavioral variability, but rather that it learns to vary between two distinct behavioral patterns—switching and repeating—with the effects of the reinforcement contingencies occurring within sequences.

According to Doughty and Galizio (2015), in contingencies that require variation, differential reinforcement teaches that long periods of switching or repeating produce less reinforcement than short periods of each (mixtures between switching and repeating). A characteristic of this interpretation, as described by the authors, is that it is possible even when assuming that the effects of differential reinforcement are limited to unitary responses or perhaps even couples of within-sequence responses (those closer to reinforcement in a complex sequence), since responses can be switched or repeated. Some of the issues raised about the notion of varying as a generalized operant extend to, in this case, the operants of "varying," "switching," and "repeating" as presented in this interpretation.

We did not find any critical commentary directed at this interpretation or at experiments aiming to test it, possibility because it is more recent. Nevertheless, a possible way to assess the suitability of this interpretation is for more studies in the field to include an analysis of the occurrences of patterns of switching and repeating throughout the experimental sessions. According to this hypothesis, the expectation is that, under variability contingencies, there is a more balanced distribution between switching and repeating—and not only an increase in switching, as is proposed by Machado (1997), which will be discussed later. In this manner, analyzing the occurrence of within-sequence switching and repeating in variability studies will help test the suitability of this hypothesis.

Interpretations for variability as a secondary effect to other processes
The literature contains different interpretations for reinforced variability that dismiss the premise that variability is an operant or dimension of a directly reinforceable operant. We present each of these below.

Variability as a secondary effect of the reinforcement of switching. Machado's (1997, Exp. 1 to 3) experiments indicated that contingencies that require switching responses over a sequence of responses seem to produce an increase not only in the frequency of switches but in the variability between sequences, even if this variability is not a contingency requirement and merely permitted to occur. In these experiments, Machado (1997, Exp. 1 and 2) reinforced sequences of eight responses emitted by pigeons only when these sequences contained a certain number of switches between two keys— variation was not required but was permitted. The resulting levels of variation were similar to those obtained with variability requirements for reinforcement. In a third experiment, reinforcement was only produced by the emission of sequences that were different from the last 25 responses (Lag 25). An analysis of the pattern of within-sequence responses led the author to conclude that even in contingencies that require variation, variability was an "an indirect effect of adjustments in changeover frequency" (p.1). In other words, "switching" was the reinforced operant in schedules that supposedly reinforced variability.

Doughty and Galizio (2015, Exp. 1) provided evidence that questioned this interpretation. Using sequences of four responses (rather than eight, as in Machado, 1997) and balancing the probability of reinforcement in switching and variation contingencies, these authors obtained greater variation in the variation reinforcement contingency than during the switching contingency.

Another issue raised by Barba (2000) concerning the interpretation that variability is a secondary effect of reinforcing switching behavior, is that most of the sequences in the selected behavioral universe in variability studies meet the criteria for switching contingencies, making it possible, therefore, to produce the reinforcer by emitting varied sequences. This makes it difficult to distinguish between switching and varying in these studies. For example, in a behavioral universe with 16 sequences of four responses on two levers, right and left, the reinforcement of sequences with two or more switches would allow for the emission of eight sequences; if the sequence contains eight responses, the size of the universe and the number and proportion of reinforceable sequences increases significantly.

We can also discuss the relationship between reinforcing switching and the stimulus control by past responding involved in the memory hypothesis. Under contingencies of reinforcement for switching, despite there being several possible sequences with the number of switches required by the schedule, results show that none of the emitted and reinforced sequences is particularly strengthened, which needs to be explained if we are to assume that variability itself is not reinforced. According to Machado's (1997) interpretation, this occurs because of the limited stimulus control by the subject's own responding. It is assumed that it would be impossible for the organism to "remember" the entire sequence, meaning that reinforcement would act on each response, or at the most on few within-sequence responses as behavioral units, and not on the entire sequence as a unit. Furthermore, the reinforcement of these small units would lead to, by generalization or response induction, an increase of the frequency of responses that are topographically similar to those that were reinforced, which would explain the occurrence of switches and not the mere selection of unitary responses. In this sense, if the switching hypothesis is correct, "remembering"—understood to be the establishment of stimulus control by past responding as a discriminative stimulus—would be detrimental to the obtained behavioral variability, decreasing it.

Negative frequency-dependent selection. In another two experiments, Machado (1989) reinforced sequences of four responses using a percentile reinforcement schedule. In this schedule, the probability of reinforcement for a certain sequence could be dissociated from the variability requirement. In Experiment 1, the author manipulated the variability requirement, maintaining the reinforcement probability constant. In Experiment 2, the author manipulated different probabilities of reinforcement, maintaining the variability requirement constant. Results showed that variability changed according with the sole manipulation of variability requirements (Exp. 1), but not with the sole manipulation of reinforcement probability (Exp. 2), indicating that reinforcement rate alone is not responsible for variability in such contingencies. In discussing these results for both experiments, Machado (1989) interpreted the resulting variability as being a product of "probability-dependent selection," which Machado and Tonneau (2012) also presented as "negative frequency-dependent selection," described as involving "the combined effects of reinforcement and extinction, one strengthening the weakest responses and the other weakening the strongest responses" (p.254).

In this interpretation, there would be differential reinforcement of less probable patterns depending on the schedule requirement, leading to an increase in behavioral variability. According to Marr (2012) and Machado and Tonneau (2012), the interpretation of negative frequency-dependent selection could be extended to other reinforcement schedules that also rely on the frequency of a certain sequence, which are used in other studies about reinforced variability (e.g., Lag *n*, threshold).

In contrast to Machado and Tonneau's (2012) assertions, Machado (1992) stated that, despite being a necessary condition for reinforced variability, negative frequency-dependent selection alone is not sufficient, since the size of the behavioral unit required for reinforcement should be taken into consideration as a relevant variable. This statement was based on experiments in which the author manipulated the size of sequences required for reinforcement, observing that smaller units, such as a single response, led to a stereotyped pattern of minimal switching, just enough to produce the reinforcer. The predictability of responding decreased as the size of the behavioral unit increased.

The balance hypothesis. In discussing the works of Machado (1989, 1992) and Machado and Tonneau (2012), as well as the aspects involved in negative frequency-dependent selection as proposed by these authors, Barba (2015) presented the balance hypothesis, which involves the idea that variability contingencies continually balance the frequencies of each alternative response sequence. Even though Barba (2015) does not characterize the balance hypothesis as being distinct from negative frequency-dependent selection, the two interpretations are differentiated by Nergaard and Holth (2020) when commenting on the articles by Machado and Barba. Nergaard and Holth (2020) considered the balance hypothesis as an adaptation of negative frequency-dependent selection. In fact, Barba (2015) presented additional commentary about the idea common to both interpretations, so we have decided to address them separately.

As Barba (2015) discussed, reinforcement and extinction, according to the balance hypothesis, would affect the response sequences and their characteristics, and not the relationship between sequences. In an ideal balance condition, all the possible variations in a behavioral universe would be equally strong. With the emission of sequences and their ensuing reinforcement and extinction based on their frequency, reinforcement would strengthen the weakest variations in that moment, and extinction would weaken the strongest in that moment.

A noteworthy aspect of the balance hypothesis is that it is not the mere combination of reinforcement and extinction that is responsible for the resulting variation. Lower values of Lag *n*, for example, involve the prevalence of reinforcement over extinction, and higher levels involve the prevalence of extinction over reinforcement. According to the hypothesis, balanced values of both would be the most effective in generating variability. This is because reinforcement and extinction are acting upon less or more frequent sequences at a given moment, which would also explain why the levels of variability are smaller in yoking conditions (with very similar distributions of reinforcement and extinction but that do not involve the selection of less frequent variations and the extinction of those that are more frequent).

According to Barba (2015), the balance hypothesis dismisses the premise of a unitary class being selected in variability contingencies, because the resulting variability is a product of the absence of a consistent selection:

Unlike Neuringer's (2002) view, the balance hypothesis assumes that contingencies based on response frequency do not engender a unitary functional class (i.e. different emitted responses or response sequences do not compose one operant class engendered by these contingencies). Such contingencies, instead, promote a dynamic interaction between the subject and its environment so that no unitary and stable functional class is produced. The balance hypothesis suggests, therefore, that unpredictable behavior is promoted and maintained when continued and consistent operant selection does not take place. When nothing is consistently selected, responding is unpredictable. Unpredictable responding is a default performance if the balance hypothesis is correct. Under contingencies based on response frequency, repertoires can remain undifferentiated and undifferentiated behavior is unpredictable. (p. 100)

Barba (2015) pointed to two limits of the balance hypothesis for reinforced variability. One of them is that the hypothesis does not explain the pattern of systematic responses generated by more lenient contingencies based on response frequency. These contingencies seem to produce response chains in which past responding serves as a discriminative stimulus for current responding, a specific selected pattern that is incompatible with the notion of undifferentiated responding. Another group of findings mentioned in Barba (2015) that is not explained by the balance hypothesis concerns the transference of performance in generalization tests, after variability is reinforced in conditions similar but not identical to those of the tests. If undifferentiated responding were produced by reinforcement based on response frequency, then we would not expect for responses in generalization conditions to be similar to responses emitted in training (because a unitary functional class, such as responses or sequences, would not have been established). However, the results are the opposite, showing that some kind of behavioral repertoire is acquired under variability reinforcement.

Dynamic process of intermittent conditioning and extinction of responses or response patterns. A similar interpretation to negative frequency-dependent selection and the balance hypothesis was proposed by Holth (2012a, 2012b, 2016) and explored by Nergaard and Holth (2020). In this latter text, the authors called this interpretation a "dynamic process of intermittent conditioning and extinction of responses or response patterns" (p. 595).

Holth (2012a, 2016) presented a set of data that led to this interpretation. By displaying different operanda (right lever, left lever, chain, photocell, and wooden lever), on which responses were initially reinforced in Lag 1 and later increased to Lag 4, he observed the establishment of chains of stereotyped responses in Lag 1 to Lag 3, with the animals alternating between four response types—a result which Holth (2012a) related to those that supported the notion of memory-based variability proposed by Neuringer—but this pattern ceased with the requirement of a fifth response to meet the criteria for Lag 4. In this case, the last reinforced response was immediately repeated after consuming the reinforcement, and, in extinction, the subjects began to vary once more, this time in a less predictable manner—a result which Holth (2012a) related to Neuringer's random hypothesis. Along similar lines, Holth (2012b) carried out a critical reading of the experiment by Pryor et al. (1969), frequently cited in the literature as an example of reinforcing "novelty," emphasizing the role of intermittent conditioning and extinction in generating variability in the study.

Based on this and other data in the literature, Holth (2012a) and Nergaard and Holth (2020) interpreted that, in reinforced variability experiments, reinforcement generally occurs (a) contingent to sequences far too complex to be strengthened (except when the schedule requirement is low); (b) following several types of responses that are directly reinforceable; (c) frequently enough so that the subject maintains responding even during periods of extinction; and (d) alongside the differential extinction of repeated behaviors. Therefore, increased behavioral variability would be explained by the cycles of reinforcement and extinction—reinforcement of several different responses (pecking and changeovers, for example), and extinction "according to patterns that are ''chaotic'' or quasi random in the sense that they are sufficiently complex for the discriminative control exerted by prior sequences to break down" (p.247). This interpretation, according to Holth (2012a), is based on well-known basic principles that are sufficient to explain the phenomenon, dismissing the need for the idea of "variability as an operant"—an idea that could lead us to believe that variability goes beyond the scope of individual responses being followed by reinforcers—and dismissing the notion of "special random or stochastic generating processes" (p. 248).

Peleg et al. (2017) conducted an experiment to test resistance to change in children's responses (pressing buttons on the left, middle, or right) when CRF contingencies turned into lag or yoked schedules. The results indicated that, during exposure to lag, all three position responses were extinguished according to the order they had been strengthened in CRF (i.e., resurgence), emphasizing the role of extinction in explaining variability under lag schedules and questioning the characterization of variability as a reinforceable operant dimension. This study complements the empirical bases that support the interpretation suggested by Holth (2012a, 2016) and Nergaard and Holth (2020), and accounts for the selection of cyclical patterns of responses in variability contingencies—patterns which, according to Barba (2015), would not be explained by the balance hypothesis and which are sometimes discussed under the memory hypothesis.

Some additional topics should be noted concerning Nergaard and Holth's (2020) interpretation of variability as a result of a dynamic process of intermittent conditioning and extinction of responses or response patterns. Firstly, the author's analysis begins with the comparison between a large group of results from variability reinforcement studies and the results of studies from other fields of investigation in Behavior Analysis, such as those that investigate the effects of temporal distance (immediacy or delay) on the effectiveness of reinforcing consequences and that investigate the establishment of smaller or larger units of responses or chains. The data suggest that the more immediate the reinforcer and the smaller the behavioral unit established by the experimenter, the greater the adjustment to the programmed contingencies—results that are opposite to those obtained in the field of variability (e.g., Cherot, et al., 1996; Odum et al., 2006; Page & Neuringer, 1985).

Secondly, Holth's interpretation (Holth, 2012a, 2012b; Nergaard & Holth, 2020) derives, at least in part, from methodological changes regarding the most common studies about reinforced variability. One of these changes is the adoption of units consisting of a few topographically discrete responses (e.g., pressing a metal lever on the right and on the left, pressing a wooden lever, nose-poking, and pulling a chain) rather than the use of several response sequences as descriptive units, which is more common in studies with non-humans, though there may be exceptions. In addition, Nergaard and Holth (2020) defended that these units should be directly trained prior to the variability contingency—a contrast to how most studies use response sequences that were not directly trained. Even when studies employ contingencies that do not require variation in baseline (e.g., CRF or Lag 0), they do not usually guarantee the selection of all possible sequences as units (e.g., 16 sequences with four responses each), meaning that, at the beginning of the variation contingencies, some sequences have already been reinforced and are part of the experimental subject's behavioral repertoire, while others are not.

According to Nergaard and Holth (2020), together with the use of free-operant procedures in experiments, these strategies allow for the isolation of the effects of other variables that could be involved in the use of sequences, such as interresponse intervals (IRI) and intertrial intervals (ITI); the complex control involved in the use of sequences as units; the differential effect of reinforcer delay on the first and last responses of a sequence; and the effects of reinforcement or timeout on the responses in the following sequence.

Another change defended by Nergaard and Holth (2020) is the moment-to-moment analysis, over sessions, of local responses (i.e., within sequences or even for each trial or unit of time) emitted by the experimental subjects in occasions of reinforcement and extinction. This type of analysis differs from aggregated analyses (i.e., per session, per block of trials, per phase) of the effects of the variability contingency, such as the analysis of the relative frequency distributions for alternative response sequences, the use of statistical tests for infrequency and independence between events, among others, which are common in the field of variability. According to Nergaard and Holth, moment-to-moment analysis facilitates the observation and identification of the effects of each aspect of the contingency in determining behavioral variability.

Avenues for the study of behavioral variability

In sum, several different interpretations for reinforced behavioral variability can be found in the literature. Even though empirical studies about variability can be conducted without directly adopting any of these interpretations, the research questions, the delineated methods, and the interpretation of the resulting data will certainly be under the control of theoretical notions about the object of study. The analysis of these ideas in the present study indicated a few avenues for future investigations about

reinforced variability that were either directly or indirectly recommended in the proposals, criticisms, and commentary of the studied authors.

The analysis of these interpretations showed that one of the main difficulties in the field is determining if response sequences can be considered, in fact, functional units in the experiments and, therefore, if the reinforcement schedules for variability act on the relations between these sequences, directly on the sequences individually, or on shorter within-sequence responses or response patterns. One of the authors' suggestions (e.g., Barba, 2012a, 2012b) was that the different measures of variability used in each study should not be considered as measures of the same phenomenon, as it is possible that differential reinforcement has distinct effects on different forms of variability (e.g., relative infrequency, non-recency, etc.).

Another aspect frequently addressed in the different interpretations for reinforced variability (both in those that define it as an operant and in those that understand it to be a secondary effect of other processes) is the role of the discriminative control exerted by responding itself (i.e., "memory") or by aspects of the variability contingency. In some of these interpretations, the existence of such stimulus control is discussed as a possibly facilitating or deleterious condition for reinforced variability, although not considered a central aspect. In other interpretations, the stimulus control generating by previous responding or by aspects of the contingency is a central aspect of the author's proposal. While considered improbable in some theories and important in others, the topic is directly involved in explanations for variability. For this reason, it is necessary for more studies, other than the ones we found, to directly investigate the role of discriminative control in variability.

Other methodological suggestions were the more frequent use of free-operant procedures and of molecular analysis of the behavioral changes produced in variability contingencies. In addition, some authors suggested establishing behavioral units prior to exposure to variability contingencies, which could, aside from clarifying aspects involved in reinforced variability, bring basic and applied studies closer together.

Finally, the main suggestion for future studies on reinforced variability that can be derived from the present analysis of existing theoretical interpretations for the phenomenon is for each study to discuss the implications of new findings for the understanding of behavioral variability and thereby establish a dialogue with existing interpretations. This suggestion is based on the premise that the mere collection of data, without a theoretical discussion, delays the refinement of the stimulus control over the verbal behavior of Behavior Analysis researchers regarding variability and, therefore, delays the development of this field.

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