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BEHAVIORAL VARIABILITY: A UNIFIED NOTION AND SOME CRITERIA FOR EXPERIMENTAL ANALYSIS*

VARIABILIDAD CONDUCTUAL: UNA NOCIÓN UNIFICADA Y ALGUNOS CRITERIOS PARA EL ANÁLISIS EXPERIMENTAL

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ABSTRACT

Variability, previously treated as experimental noise, has become the object of systematic study. In studies of behavior there has been a high level of consistency in data referring to the initial appearance and maintenance of variability. However, research on behavioral variability includes theoretical/conceptual questions that still need to be addressed. This paper discusses the concept of variability and proposes criteria for encompassing the wide range of existing research and other work yet to be produced in this area. It is suggested that the difference between behaviors constitutes the property common to the universe of variable behaviors, and that this property can be modified or induced by reinforcement. If this is the common property of behavioral variability, the various uses of the term can be understood and grouped from a small number of criteria employed in scientific methodology. We consider the characteristics or properties in the units involved, the complexity and number of such units,

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the quantitative or qualitative type of the units and comparisons between them, and whether the units are considered in molecular or molar terms.

Key words: behavioral variability; induction; reinforcement; learning; conceptual analysis.

RESUMEN

Además de ser contemplado como ruido experimental, la variabilidad ha sido considerada objeto de estudio sistemático. En los estudios conductuales sobre el tema, los datos presentan un alto nivel de consistencia respecto a su aparición y mantenimiento. Sin embargo, la investigación sobre variabilidad conductual contiene cuestiones teórico-conceptuales que aún precisan ser consideradas. El artículo analiza el concepto de variabilidad, y propone diversos criterios para estructurar el amplio rango de investigación existente, y también para orientar trabajos futuros sobre el tema. Se plantea que la diferencia entre conductas constituye la propiedad común al universo de variabilidad conductual, y que esta propiedad puede ser inducida y modificada por reforzamiento. Asumiendo esa propiedad común de variabilidad conductual, los diferentes usos del término pueden ser entendidos y organizados a partir de un corto número de criterios utilizados en metodología científica. Consideramos así las características o propiedad de cada unidad conductual tenida en cuenta, la complejidad y número de tales unidades, el tipo cualitativo o cuantitativo de ellas y de sus comparaciones, así como si tales unidades son consideradas en términos molares o moleculares.

Palabras claves: Variabilidad conductual, inducción; reforzamiento; aprendizaje; análisis conceptual

In science, variability can sometimes be considered a problem of poor experimental control. As such, it must be minimized. But it can also be understood as part of the phenomenon in focus, becoming the object of systematic analysis. In this sense, variability has been studied in many sciences (Bütz, 1995; Fivas, 1994; Thelen & Smith, 1994), so that laws are now sought to explain variability as well as other more consistent phenomena (Doll & Freeman, 1986).

From a behavioral perspective, variability can be considered from two different standpoints: its initial appearance and its maintenance, both related to some environmental contingencies. In some studies, the emergence of variability is a result of the contingency but is not directly reinforced by it. In other cases, the variability is itself the criterion for reinforcement, so its maintenance is dependent on its consequences.

For example**, Antonitis (1951) reinforced rats for poking their nose anywhere along a 50-cm horizontal strip, which was divided into 50 intervals (1 cm apart).** In this study, variability was measured as the different points touched by the rat. In comparison with the operant level, the variability of these responses was reduced in conditions of continuous reinforcement and significantly increased in extinction. Results such as these suggest that extinction may induce behavioral variability. Similarly, some authors have observed that intermittent reinforcement schedules (which necessarily require periods of extinction) also produce an increase in behavioral variability, especially those schedules involving time, such as a fixed or variable interval (Boren, Moerschbaecher & Whyte, 1978; Eckerman & Vreeland, 1973; Ferraro & Branch, 1968; Stebbins & Lanson, 1962). These studies investigated some environmental conditions that induced variability and suggest that variable behavior can be indirectly produced by contingencies of reinforcement, independent of its differential consequences.

A second line of research analyzes variability as any other behavioral property that can be controlled by its consequences. In such studies, the experimental setting specifies behavioral variability as a condition for reinforcement. In a prototype experiment (Page & Neuringer, 1985) with pigeons, sequences of eight key-pecks on two keys (right-R and left-L) were reinforced. The sequences of responses were evaluated by comparing the distribution of R or L responses in each one (for example, the sequences RRLLRLRL and RRLLRLRR differ in the last response). It was shown that the variability of the sequences 1) increased when reinforcement was contingent on a sequence that differed from the previous “n” sequences; 2) decreased when this requirement was eliminated; and 3) came under stimuli control. These results were replicated in different experiments that demonstrate the operant nature of variability, placing the selection of both variable and repetitive behavior on the same dimension of control by consequences (Neuringer, 2002; 2004). Consequently this second research program is more directly related to the maintenance of variability, identifying the selection by consequences as the critical process.

Despite the agreement about the aspects mentioned above, certain conceptual/methodological questions should be considered. One of the most important questions concerns to the absence of conceptual uniformity. Analyzing some empirical works, Barba (2006) suggested that behavioral variability studies have been using at least four different concepts of variability: (1) dispersion around a central tendency value; (2) distributive uniformity (equiprobability); (3) recency, and (4) sequential dependence.

The notion of variability as *dispersion* (e.g., Antonitis, 1951; Eckerman & Lanson, 1969) assumes that behavior becomes more variable the more it departs from a central value. Behavior is, therefore, analyzed through indicators such as variance or standard deviation.

Variability considered as *equiprobability* of distribution among all instances of responses is studied through the distribution of values across the universe of possibilities, considering that the more equitable the distributions of the events, the greater will be the degree of variability (as in Ferraro & Branch, 1968; Hunziker, Saldana & Neuringer, 1996; Machado 1989; 1992; 1993; Neuringer, 1986; 1991; 1992; Page & Neuringer, 1985; Stokes, 1995). On the *continuum* of degrees equiprobability is the maximum of variability, measured by a statistical index (U) that indicates uncertainty, derived from information theory (Attenave, 1959).

Recency assumes that variability is related to the temporal distance that separates one instance of response from the other instances of the responses of the same class (as in Machado, 1989). Considering sequences of different classes of responses, the distance between two similar responses can be measured by the number of different intervenient responses. In this case, recency is inversely related to the variability.

Sequential dependency is related to the notion of independence among the events, such as the independency of the occurrence of numbers when one rolls a dice. Experiments had studied the level of the independency between the emission of two responses (for example, pecks on the right or on the left key, by pigeons, as in Machado, 1992). The chi squared (as in Blough, 1966) or the Markov chain (as in Machado, 1992) are some of the statistical tools for measuring the independency among events.

Besides the various different behavioral concepts, there is a wide diversity of behavioral characteristics and situations in which variability is identified, i.e., the diversity of the dependent variables studied in animal and human variability researches. Among others, variability has been analyzed with interresponse times (Blough, 1966), sequences of responses on two or more *manipulanda* (Machado, 1992, 1997; Mechner, Hyten, Field & Madden, 1997; Neuringer, 1992; Page & Neuringer, 1985; Schwartz, 1980, 1982; Shimp, 1967;Wagner & Neuringer, 2006;), **poking their nose anywhere along a 50-cm horizontal strip** with rats (Antonitis, 1951), response duration (Cruvinel & Sério, 2008), and response topography (Stokes, 1995). Some of these properties have also been identified in word associations (Maltzman, 1960), **block buildings that differed from one another (Goetz and Baer, 1973),** while in the work of Pryor, Haag and O'Reilly (1969) **porpoises were reinforced for jumping, turning, or swimming in novel ways. The diversity on these dependent variables is not a problem,** ***per se*****, but it can contribute to the ambiguity in variability studies considering the absence of a precise definition of the phenomenon.**

The differences in the notion of variability can generate different conclusions about the same data, with the consequent risk of ambiguous and inaccurate analyses. For example, in Antonitis's study (1951, Experiment 2), let us consider two opposite behavioral patterns: (1) the location of a rat's responses only at the extremes of the *operandum* –which would indicate a high index of dispersion with respect to the mid point-, and (2) the similar distribution of the responses throughout the 50 intervals –which would indicate equiprobability of responses. Considering just the concepts of dispersion and equiprobability, each pattern can be classified as variability or repetition depending on the adopted definition. So, adopting the notion of variability as dispersion, the first pattern is the most variable. On the other hand, adopting the notion of variability as equiprobability, the opposite conclusion is reached: the second pattern is deemed more variable (Barba, 1996).

Given the existence of different notions, and if we consider that reinforcement strengthens a class of responses, we might ask, like Schwartz (1982) did: what is the objective property that characterizes different responses as belonging to the same class of variable responses? In other words, studying reinforcement of variability would require the definition of the objective property that in turn defines the class of responses reinforced. The lack of this consensus is related to another matter regarding doubts about the nature of variability. It is sometimes considered as an *operant behavior*, that is, a behavior, and at other times as a *dimension or property of operant behavior*, akin to strength, duration, latency and topography of response, among others (Neuringer, 1991; Page & Neuringer, 1985).

The study of variability would, therefore, benefit from a conceptual analysis that makes it explicit a property that covers all the different definitions and mentions of variability, bringing greater integration and clarity to the matter. The present paper suggests that this property can be obtained by abstracting the common ground from the different definitions of variability.

Given that the variety of uses of the term variability in the literature will continue to exist and lead to different conclusions, it is useful to consider some criteria that can organize such variety of uses. These criteria can be taken from those proposed by the methodology for describing and prescribing the work of scientists (Moreno, Martínez & Chacón, 2000).

A COMMON DEFINITION OF BEHAVIORAL VARIABILITY

Behavioral variability refers to the differences or changes among behaviors that occur at different moments or in different spaces, while repetition refers to a case of equality of behaviors. These *differences or changes are the com-*

mon property to all cases of behavioral variability. Sometimes such differences are measured by taking one of the behaviors as a fixed reference, such as in the notion of dispersion (e. g. in Antonitis, 1951, in relation to a central value). In other cases, differences are established among different behaviors, which thus act as successive and variable referents, as occurs with the notion of equiprobability (as in Page & Neuringer, 1985, using the procedure named LAG). In all cases, behavioral variability is a property that emerges from the comparison of certain behaviors with its *referents* (one fixed behavior or varied ones), and always refers, therefore, to a set of responses. In this sense, it is a property similar to others, such as the interval between responses, and different from properties of individual responses, such as topography, strength or duration of each one of these. Comparisons must be made between properties of individual responses or sets of them. As mentioned above, the variability of properties has been studied with responses topography (Stokes, 1995), interresponse times (Blough, 1966), responses location (Shimp, 1967; Machado, 1992, 1997), and responses duration (Cruvinel & Sério, 2008), among others.

Despite the diversity of procedures and properties considered, behavioral variability is simply the existence of *differences or changes between properties of responses analyzed.* This is the characteristic that defines the class of variable responses that can be induced or reinforced as shown in the literature, and which answers the question raised by Schwartz (1982). It also permits us to answer whether variability refers to an operant behavior or a dimension of that type of behavior. Variability is conceived as a characteristic that can be identified in behavior. The literature also shows that on analyzing the behavior of organisms in terms of variability such behavior fits the defining criteria of operant. Thus, variability is a way of considering operant behavior, just as it can be considered in terms of strength of responses or interval between responses. The references to behavior must always be made in terms of some property, variability being one of them. Rather than making a choice between whether variability is an operant or a dimension of behavior, it seems reasonable to understand variability as a property of operant behavior.

The property of *difference between behaviors* becomes more significant when specifying or defining the behavioral units and universe considered in each reference to “variability”. By *behavioral unit* we mean each of the compared behavioral instances or sets, and whose differences or changes define the phenomenon. By *behavioral universe* of variability we mean the set of units and comparisons that define the phenomenon. *Variability should always be defined as a comparison among units from the same universe*. For example, in the study by Page and Neuringer (1985), where the requirement was sequences of eight responses of pecking two disks (right-R and left-L), the universe of analysis was the 256 possible sequences and the unit of analysis was each eight-response sequence emitted. In that study, the responses probably differed in their duration, interval or strength, but such properties fell outside the universe of analysis proposed by the authors, and were thus not considered.

In each study, the unit and universe of variability are defined *conventionally*, in the sense that this definition depends on the theoretical viewpoint or the decision of the researchers. For example, in the context of behavior generated by a fixed-interval schedule of reinforcement (FI), the universe of variability could be the set of responses that occurs in an interval, while the unit would be each of the responses in that interval. This same set of behaviors may also constitute the unit of variability when analyzing whether there are differences or changes among the intervals of an experimental session. Those intervals would constitute the universe of variability. Depending on researchers' conventions and decisions, the identification of units and universes may be performed in different ways, meeting different criteria.

CRITERIA FOR CLASSIFYING DIFFERENT USES OF VARIABILITY

Units and universes –and therefore variability- may have differing levels of *complexity*. For example, the simplest universe of variability consists of a single comparison between two simple units, as in the case of considering the difference between the strength of two responses. Other universes of variability are composed of different comparisons made between one simple unit and several others. This is the case of different comparisons between a series of response values and a value taken as central, as it occurs in the analysis of standard deviation. Finally, other universes of behavioral variability involve one or several comparisons between composed units, as when different response sequences are compared (as in Page & Neuringer's study, 1985).

Every behavioral unit, and its comparison with any other behavior, can be specified on different qualitative or quantitative levels. A *qualitative* criterion indicates whether the two values of this behavior, or their comparison with any others, are equal or different. If any two values of the behavior or of its comparison with any other are different, the distinction between whether each value is higher or lower than the rest would correspond to the *ordinal* mode of specification. If there is an indication of *how much* difference there is between two values, the specification is *quantitative*. The same study may tackle different levels of analysis, as can be seen in Hunziker, Saldana and Neuringer (1996), where sequences of four pressing responses on two bars were reinforced –right R and left L-, with reinforcement contingent either on the difference between the sequences of the responses emitted, or independent of this difference. The qualitative level of analysis appears in the comparison of the distributions of R and L responses within the two sequences. The quantitative analysis was based on the frequency with which each of these sequences was emitted.

Universes of behavior can be considered in two ways: detailing different units or components –which implies a specification on a *molecular* level– or considering them globally and abstracting the different components of the behaviors and their variability. This would mean observing on a *molar* level. For example, in the study of behavioral variability, Neuringer and colleagues analyzed variability in a fundamentally molar form, with a predominance of the analysis on how predictable are the sequences emitted during an experimental session (for example, Hunziker *et al*., 1996; Morgan and Neuringer, 1990; Neuringer, 1986; 1992; 1993). In addition to performing molar analyses on the set of behavior over the course of the sessions, Machado (1993; 1997) performed molecular analyses to identify the level of dependence between the location of each response within the sequence and its probability of emission. His intention was to isolate the nature of the behavioral variation and the processes underlying it.

CONCLUSIONS

Behavioral variability is a construct that has been used in the literature in different settings or related to very specific characteristics. To define behavioral variability one has to adopt the basic requirement of difference or change between behavioral units of a given universe. Variability is the difference between certain units of a given universe, regardless whether such differences are measured in terms of dispersion, equiprobability, recency or sequencial dependence. The *difference* among units of a certain universe is the property that defines the class of operant responses considered as variable, and which can be induced and reinforced, as shown by many studies. The concept of variability consists of the comparison between units of response, and cannot, therefore, be considered in terms of any individual responses.

The characteristics and settings considered in the behavioral units compared the variable or fixed character of the units taken as references in the comparisons, the complexity and the qualitative/quantitative type of the units and comparisons between them, and whether they are considered in molecular or molar terms. All of these are methodological criteria that introduce their specific cases with which to characterize and group the wide range of possibilities of differences described as variability.

Inevitably, the specific concept of variability may be different depending on the criteria analyzed. However these serve as an explicit and common reference for appreciating similarities and uniformities in the data on each one of the accepted meaning and uses of variability. It brings greater organization to present and future data. The appraisal of *variability depends on the units and universes considered.* A series of data such as 3, 4, 5 is variable if the universe comprises each number as a unit, but it is regular or stable if the universe is a series made up of several repetitions of these three values. Variability appraisal also depends on the property considered in the units; they may vary in frequency but not in topography, or in strength but not in spatial location. They may also change as a result of the measurement used. The series (0,9,0,9,0,9) is more variable than the series (0,1,0,0,0,1) if the variability construct is in terms of range but it is less variable in terms of the differences between the successive values. Similarly, the variability that occurs when the molar level is considered may not necessarily be the same as that which occurs when the molecular level is considered. In the example of behavior obtained under an FI schedule, we would have, on a molar level, a recurrent or repetitive pattern: the response frequency is low or zero after reinforcement, with a subsequent increase before the end of the interval. On the other hand, the molecular analysis of the behavior within each interval reveals great behavioral variability, suggesting different controls over the behavior at each moment of the interval (Morse, 1966).

Given that variability can be defined in different ways and considered with different criteria, *before characterizing a behavior as variable it is essential to clarify the concept of variability employed* and t*he criteria with which it is being considered*. Although it is possible to consider a common notion for all cases of behavioral variability, it is critical to emphasize that variability should be studied not as if it were a unitary concept, but rather according to the criteria considered in each case.

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