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## **Selections on the Empirical and Theoretical Investigations of Behavioral Variability: An Introduction to the Special Issue**

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*This special issue of the International Journal of Comparative Psychology is dedicated in memory of Seth Roberts who passed away before its publication. The ideas contained herein are in part the result of, and greatly inspired by, his innovative and important work on behavioral variability.*

**“Under carefully controlled experimental circumstances, an animal will behave as it damned well pleases.”**  
**-The Harvard Law of Animal Behavior**

Though the Harvard Law is much a tongue-in-cheek, wry statement for researchers to evoke when their investigations do not go as planned, it holds a critical reminder for those who would set out to forecast the behavior of organisms. Namely, it suggests an important role for the unpredictability inherent to behavior. The Law subtly indicates that this unpredictability is neither due to measurement error, nor due to an incomplete understanding of the factors that control behavior, nor owing to improper control of the relevant observational parameters. Instead, due to intrinsic stochasticity, behavior retains a degree of *necessary* unpredictability. In other words, while researchers can readily make accurate predictions regarding typical behavior when collecting many data, they must necessarily struggle to accurately predict a single organism's behavior at a given instant in time. Behavior appears to be probabilistic in nature, not determined.

The experimental investigation of behavioral variability as an important phenomenon, rather than a nuisance, has really only entered the scientific literature in very recent decades. Certainly, there were investigations that predate the so-called cognitive revolution (e.g., Antonitis, 1951; Dashiell, 1930); however, the systematic investigation of behavior has traditionally focused on the strength of discrete response classes, rather than the examination of the control of the form of behavior. Much of this focus may be attributable to the giant intellectual forebears in the studies of classical conditioning and instrumental learning. Thorndike's (1911) law of effect focused on the lawfulness of how Stimulus-Response (S-R) learning follows from

reinforcement. Skinner's (1966; 1970) work was particularly influential and emphasized the probability of the operant response, while paying little mind to the systematic variability inherent to the behavioral data he collected. Epstein (1991) took note of this stance, suggesting that "nontrivial mechanisms of variation might have made the organism seem a little too autonomous for Skinner's liking" (p. 365).

No doubt that some of the emphasis on response strength from the earlier years of the experimental investigation of behavior was due to technological limitations. Many hundreds of papers were published with the relevant data being merely the frequency and pattern with which an animal closed a switch (e.g., the identification of whether a lever press or key peck had occurred). Skinner and his contemporaries did not have ready access to advanced apparatuses and software that could record with great precision the duration of lever presses, much less capacitive touchscreen computers that can both present complex visual stimuli and record with great precision the spatial coordinates of a given response (e.g., a peck). Perhaps if he had, the brand of science he proffered would have been substantially different in scope.

In recent years, the field has acquired an appreciation of the causes and functions of behavioral variability. The Harvard Law of Animal Behavior still holds true, but we have been able to uncover some of the fundamental factors that control the amount of variability with which animals behave. We have gained a greater understanding of the neurobiological systems that govern the production of behavioral variability (e.g., Brembs, 2011; Schmidt & Ding, 2014; Woolley, Rajan, Joshua, & Doupe, 2014). We have also discovered empirically, in many cases, why intrinsic variation in behavior allows the animal to accomplish its goals; in other words, we know how variability may translate to adaptive behavior (e.g., Neuringer, 2004).

We present this issue of the *International Journal of Comparative Psychology* as a brief examination of many aspects of the empirical investigation of behavioral variability. We are fortunate to be able to include a number of contributions by esteemed and prolific behavioral scientists, as well as articles by early-career researchers. To all of them, and to all the reviewers and *IJCP* editors who made this issue possible, we owe a debt of gratitude.

Contributions to the special issue include a number of review and theoretical papers. Heather Bell contributes an article that offers an alternative, cybernetics-based view of behavioral variability and the advantages it offers the organism. Allen Neuringer, a leading authority on associative learning and operant variability, contributes a theoretical paper examining the role of behavioral stochasticity as possible evidence for the evolution of volition. Karen Pryor and Sheila Chase revisit a classic paper (Pryor, Haag, & O'Reilly, 1969) on the explicit training for variable behavior in cetaceans and reflect on the use of the marking procedure to generate novel action. Charles Shimp delivers a paper that examines the quantitative analysis of behavioral variability from both molecular and molar perspectives, and provides reasons why we should study behavior with an eye towards combining them. The late Seth Roberts delivers an enlightening commentary on how little thought is given to the origins of behavior in both the fields of human learning and behavioral economics.

We are also proud to offer several works of novel empirical research on the topic of behavioral variability. Roger Bartlett and his colleagues report a case study in which they investigated transitions between ambulatory states (e.g., walking to running) and the possible role of self-organizing maps. Wally Herbranson and his colleagues report an experiment with pigeons in which they inserted random distortions into established response sequences and examined the degree to which performance was disrupted. Mélanie Kaeser, Pauline Chatagny, and their co-authors report on inter- and intra-individual motor learning in macaque monkeys, and find that variability in the monkeys' behavior decreases with increased opportunities for motor learning. Ken Leising and colleagues report on how rats' variability in behavior is dependent on the spatial relationship between an operandum and the location at which reward is delivered. Finally, Deborah Racey and Michael Young report on an experiment utilizing a multi-armed bandit task to examine the relationship between exploitative and explorative behavior in human participants.

The study of behavioral variability continues to grow in importance and gather interest. A thorough understanding of the fundamental processes by which variation is generated and by which it is adaptive is potentially important to our understandings of a whole host of phenomena, including all types of learning, from basic skills to language and thought (Bateson & Martin, 2013) as well as the antifragility of complex systems (Taleb, 2012). This issue represents a brief look into an important scientific enterprise, extraordinarily vast in scope and implications (Brembs, 2010). Even if we accept a fundamental unpredictability to animal behavior, this does not preclude us from studying the nature of that unpredictability.

Please enjoy the issue, and may it inspire your own creative variations.

*Sincerely,*

*W. David Stahlman and Aaron P. Blaisdell.*

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