Perspectives on Behavior Science (2019) 42:869–887
https://doi.org/10.1007/s40614-019-00212-3

Culturo-behavioral Hypercycles and the Metacontingency: Incorporating Self-Organizing Dynamics into an Expanded Model of Cultural Change

Jonathan Krispin [1,2]

Published online: 1 July 2019

Abstract

Selection by consequences is a causal mode that operates across multiple levels of analysis including in biological organisms via natural selection, and at the levels of individual (via operant contingencies) and cultural behaviors (Skinner, 1953, *Science, 213,* 501–504, 1981, 1988, 1989; Glenn in *The Behavior Analyst, 11*(2), 161–179, 1988, *The Behavior Analyst, 27*(2), 133–151, 2004). The common dynamics of systems within which selection by consequences operates has led to attempts to develop an interdisciplinary understanding of adaptation. The metacontingency (Glenn in *The Behavior Analyst, 11*(2), 161–179, 1988, *The Behavior Analyst, 27*(2), 133–151, 2004) has been proposed as a process of cultural-level selection, but this proposal has been challenged in several critiques. First, several theorists have suggested that the metacontingency addresses within-groups processes of selection that have already been addressed by more parsimonious theories. Second, principles of self-organizing systems, should they apply within cultural settings, may significantly limit the efficacy of the metacontingency as a construct of cultural analysis. More recently, additional processes of selection, the selection of cultures and cultural selection (Couto & Sandaker in *Behavior & Social Issues, 25,* 54–60, 2016) have been suggested as between-groups processes of selection, operating at a level higher than operant selection, and fulfilling the role of cultural-level selection as proposed by Skinner. In the present article, these new processes will be considered in light of principles of self-organization and the conditions within which self-organization may occur. The culturant hypercycle, the operant hypercycle, and interactions between the two (culturo-behavioral hypercycles) are defined as self-organizing processes that help to explain how the selection of cultures and cultural selection may occur. Further, the theory of self-organizing systems is used to explain how self-organizing dynamics may emerge via metacontingencies, reintegrating the culturant and metacontingent selection into an expanded model explaining processes of cultural evolution.

Keywords Cultural-level selection · Metacontingency · Selection of cultures · Cultural selection · Self-organization · Culturant hypercycles · Operant hypercycles Culturo-behavioral hypercycles

One of the fundamental tenets of behavior analysis has often been summarized in the following sentence, “Behavior is a function of its consequences” (Glenn, 2004, p. 134). The three-term behavioral contingency, consisting of the antecedent(s), a recurring behavior (operant response), and its consequences form the process through which the future likelihood for the occurrence of a given response is either strengthened (reinforced) or weakened (punished). Glenn and Malott (2004, p. 99) described it in the following manner, “Relations between characteristics of organisms or behavior and their environments determine future frequencies of those characteristics. These relations have been called ‘contingencies of selection’ (Skinner, 1981).”

Similar processes of selection by consequences have played an explanatory role in a number of scientific fields beyond behavior analysis, including biology (in the form of natural selection) and cultural anthropology (Mawhinney, 1992), and more recently in ecology (Ulanowicz, 2009) and economics (Kauffman, 2000). This common appeal to selection by consequences has led to numerous efforts to integrate concepts from these fields into a larger, multidisciplinary understanding of evolutionary and adaptive processes that spans these widely varying levels of analysis (Biglan, 1995; Glenn, 1988, 2004; Harris, 1979). Above the level of natural selection, Skinner (1981) specified operant selection and cultural selection as the levels of selection responsible for governing the interaction of living systems in the world around us. Although operant selection is well understood, cultural selection, which Skinner believed operated above the level of operant selection without requiring any new behavioral processes (Skinner, 1984), is not as clearly understood.

Glenn (1988, 2004) made a first attempt at defining a model of cultural selection intended to satisfy this level of selection as identified by Skinner (1953, 1981). Her attempt focused on metacontingencies that resulted when an aggregate product, produced by a chain of interlocked behaviors, was selected by a receiving system. She proposed that the processes of selection constituted a new, emergent level of selection operating at a level higher than operant selection. She hoped that, when paired with processes of operant selection, the metacontingency might broaden our understanding of selective processes at work in the world around us. However, recent arguments have been made that challenge the assertions that Glenn and others (see Houmanfar & Rodrigues, 2006; Houmanfar, Rodrigues, & Ward, 2010; Smith, Houmanfar, & Louis, 2011) have made regarding the metacontingency. These challenges have centered on two different underlying issues. First, several authors have suggested that the concepts expressed in the metacontingency have already been addressed by other, more parsimonious theories, making the metacontingency superfluous (Krispin, 2016; Marr, 2006; Mattaini, 2004, 2006; Zilio, 2019). For example, Krispin (2016) argued that metacontingent selective processes cannot be differentiated from the selective processes involved upon the selection of a complex product produced by an individual by an external receiving system.

The second challenge, which will be addressed in more detail here, has suggested that the efficacy of the metacontingency, and, by extension, Behavioral Systems Analysis (BSA) given its close kinship with the metacontingency, as constructs for analyzing cultural phenomena may be severely limited by principles of self-organization as expressed in systems theory.

In the present article, we will begin by quickly reviewing the model of selective processes at work in cultural settings that Glenn (2004) proposed, contrasting some of its tenets with characteristics of self-organized systems. This discussion will be followed with the presentation of a new conceptualization of cultural selective processes, building on the work of Couto and Sandaker (2016) and Krispin (2017). Couto and Sandaker (2016) have proposed two new processes of cultural selection, *selection of cultures* and *cultural-selection*, on which Krispin (2017) expanded in proposing what we will term a *culturant hypercycle* as an example of a mechanism through which the selection of cultures and cultural selection might occur. The constructs that Krispin (2017) proposed are based heavily in the theory of self-organized systems (TSOS), whereas the metacontingency is rooted more generally in biology and behavior analysis, so considerable attention will be given to comparing and contrasting these two similar, yet distinctive, approaches. Finally, the principles of self-organization and the conditions within which this phenomenon is possible will be articulated and then applied to understanding dynamics of self-organization as they may occur in the metacontingency. These processes and processes of operant selection interact together to produce many of the changes we observe in our surroundings.

The Metacontingency: A Seminal Attempt at Creating a Comprehensive Model of Cultural and Behavioral Evolution

Glenn (2004) attempted to provide one of the first comprehensive accounts linking individual behaviors to cultural and social change, including Skinner's proposed cultural selection, via processes of selection by consequences. She began with the operant and the familiar three-term operant contingency. Behaviors, occurring in the presence of antecedents, are differentially reinforced via consequences that follow, resulting in recurring lineages of behavior (the operant). In a cultural setting, many of these behaviors occur within a social environment where the behavior of other people affects the behavior of a learner or performer. Glenn (2004) noted that human cultures display the unique characteristic that most of the learning accomplished by humans is supported predominantly by the social content in the contingencies. She defined culture as patterns of learned behavior transmitted socially, as well as the products produced by that behavior (objects, technologies, organizations, etc.).

In this framework, Glenn (2004) asserted that cultural phenomena, therefore, are defined by a supra-organismic locus in that one organism's behavior serves as the context or consequences in the operant contingencies accounting for the behavior of another organism. When this occurs, it results in culturo-behavioral linkages via interlocking behavioral contingencies (IBCs). Within a culture, the similarity in the environments within which behaviors develop leads to similarities in behavioral content across individuals that Glenn (2004) termed cultural practices.

Given this context, Glenn (1988, 2004) proposed the metacontingency as a process by which Skinner's proposed level of cultural selection might occur. Metacontingencies result when chains of behaviors, linked through interlocking behavioral contingencies, form an integrated unit that results in the production of an aggregate product. The selection of this aggregate product by a receiving system provides consequences that apply across all of the behaviors in the chain. According to Glenn (2004), this potentially results in the recurrence of the interlocked behaviors, creating a *meta*contingency via emergent, cultural-level processes of selection that are substantively different from the behavioral selection processes that occur at a lower level (see also, Houmanfar et al., 2010). Hunter (2012) labeled this recurrent, integrated unit of interlocked behaviors producing an aggregate product a *culturant* to parallel the behavioral-level operant, a term accepted by Glenn et al. (2016).

The Theory of Self-Organizing Systems and Challenges to the Metacontingency

The integration of systems theory with behavior analysis has a long history. For example, the philosophical underpinnings of BSA find their roots not only in behavior analysis, but in systems theory as well, notably General Systems Theory (GST) as defined initially by von Bertalanffy (1968; see also Brethower, 1999, 2008; Hyten, 2009). Although Glenn (1988) did not originally base the metacontingency in systems theory, subsequent researchers have integrated the metacontingency and the behavioral systems approach (see, for example, Abernathy, 2009; Malott, 2003). This integration is not new and has widely been accepted in behavior analysis, both in theory and in practice. However, recent arguments have been made that assert that efforts to integrate these fields have perhaps overlooked some areas of systems theory that may threaten the efficacy of these attempts to both explain social phenomena and construct effective interventions. Mattaini (2004, 2006), for example, asserted that advances made in the study of a particular class of systems, self-organizing, or autopoietic (self-making) systems may have significant implications for and may even "fatally wound the metacontingency" (Mattaini, 2006, p. 69). Mattaini (2006) observed that self-organizing systems include all living systems and some others, but conceded that, although cultural systems appear to be self-organizing, it has yet to be proven conclusively that they are.

Although GST has numerous commonalities with the theory of self-organizing systems, there are several particularly relevant points of divergence as well. The threat that the self-organization of systems may pose to the application of the BSA/ metacontingent perspective stems from these points of divergence. One point of divergence that Mattaini (2004, 2006) articulated hinged on differing approaches used to define the boundaries of a system. Earlier versions of systems theory such as GST often suggested that system boundaries could be arbitrarily determined according to the interests of the observer. This perspective fits nicely with the metacontingent perspective and the perspective taken in BSA. For example, Hayes, Dubuque, Fryling, and Pritchard (2009) proposed that we may define a behavioral system as, "an entity comprised of interdependent elements formed by individuals interacting toward a common goal" (p. 316). This perspective is also explicitly adopted by Glenn and Malott (2004) in their attempt to place IBCs and metacontingencies in the context of formal organizations. In contrast, Mattaini (2006) pointed out that the theory of self-organizing systems (TSOS) instead asserts that these systems construct their own boundaries (see also Hudson, 2000; Mattaini, 2004). He argued that attempts to define a system in such a manner might inadvertently exclude factors key to understanding the broader dynamics occurring in an environment.

A second noteworthy point of divergence is that, for self-organizing systems, the key factors determining the dynamics are internal to the system itself, not the result of events happening outside the system boundary (Mattaini, 2006). These dynamics include, for example, the construction of the system boundaries and responses of the system to interactions with its environment. This creates the possibility, for example, that a relatively small perturbance of the system at its boundary may result in wide, sweeping changes within the system. On the other hand, it may also be true that perturbations at the boundary of a system may have little or no effect at all on the system (see Hudson, 2000). Mattaini (2006) asserted that if these nonlinear responses between efforts to influence a system and its response hold true for cultural systems, then clarifying any metacontingent relationships will not necessarily lead to prediction or control of what happens within a cultural system. Given these points of divergence and conflict with the tenets of self-organizing systems, Mattaini (2004, 2006) questioned whether it was necessary to include the metacontingency as an essential element in the conceptual framework needed to assess cultural phenomena.

Hudson (2000) outlined several characteristics that are exhibited by self-organizing systems that characterize these emergent patterns. First, the system may transform, exhibiting structures or organizations of a higher level (greater order) than that which preceded the transformation. These organizations manifest as functional, spatial, and/or temporal patterns that are sustained on a scale that is typically magnitudes of order larger than those that typified the system prior to the transformation. Second, the order exhibited emerges with a minimum of specific external interference. Finally, these structures/organizations appear with "apparent spontaneity" (Hudson, 2000, p. 551).

Culturant Hypercycles: A New Conceptualization of the Evolution of Cultures and Cultural-Level Selection

In addition to the challenges to the metacontingency as a process of cultural selection that we have already discussed, several other potential issues have been raised (see Couto & Sandaker, 2016; Krispin, 2016). Couto and Sandaker (2016) based their argument against the metacontingency as a process of cultural selection on a distinction made by Skinner (1988). Skinner differentiated the selection of cultural practices from cultural selection. In making this distinction, he asserted that the evolution of cultural practices is analogous to the evolution of particular organs *within* a species. In contrast, the evolution of cultures, or cultural selection, is analogous to the evolution of the species that results from competition *between* species as they compete for available resources in their niche in the ecosystem. Therefore, cultural selection occurs at a level higher than the selection of individual cultural practices. This led Couto and Sandaker to conclude that selection processes at work within the metacontingency constitute processes by which the selection of cultural practices occurs via *within-group* processes, whereas the selection of cultural-social environments occurs via *between-groups* processes and therefore at a higher level of selection. They asserted that the selection processes that govern metacontingent selection operate at a *within-groups* level and were, therefore, not processes of cultural selection.

In place of the metacontingency, Couto and Sandaker (2016) proposed two new selection processes that operate between groups and that might be underlying the evolution of cultures. The first of these new processes, termed *selection of cultures*, involve processes through which the cultural-social environments, or environmental settings, within which the cultural practices of a particular culture occur, are selected. The second of these new processes, termed *cultural selection*, occurs when these environmental settings then influence individual behaviors within the culture via stimulus control. Krispin (2017) described several examples of how the processes of selection of cultures and cultural selection may occur, utilizing, in particular, a definition of feedback that is broader than the concept as used within behavior analysis. According to this definition, on which we will rely in the present context, feedback occurs when the outputs of one cycling of a system serve as inputs into the next cycling of a system, forming a system that is not just recurrent, but *iterative* as well. This definition of feedback is consistent with the use of the term in systems theory, but also in related fields such as cybernetics and systems dynamics (see, for example, Ashby, 1957; Forrester, 1968; Senge, 1991; von Bertalanffy, 1968), and also, as we will see, in the TSOS. In fact, feedback is a defining feature of a system, and can occur in two fundamental varieties—positive feedback and negative feedback. Positive feedback occurs when the input amplifies the intensity, frequency, rate, acceleration, etc. of the activity in the subsequent cycling of the system, whereas negative feedback produces the opposite effect, dampening the intensity, frequency, rate, acceleration, etc. of the activity in the subsequent cycling of a system.

In Krispin's (2017) examples, the processes of selection of cultures and cultural selection result when positive feedback loops of metacontingencies, or what we will call *culturant hypercycles*, form (the term *hypercycle* is adopted from Eigen and Schuster [1979] for the name that they gave to collectively autofacilitative sets). In a culturant hypercycle, a set of culturants forms such that, for each culturant included in the system, the culturant both selects an aggregate product produced by another culturant in the system as an input into its process *and* itself produces an aggregate product that is selected by another culturant in the set. Given that this is the case, the constituents in this set form a closed loop, feedback system of metacontingencies (see Fig. 1). When, for each culturant in the set, the selection of the aggregate product provides an advantage to the subsequent culturant in the set, the feedback system becomes a positive feedback loop and collectively accelerates the rate of activity for all culturants in the set.

When such sets form, they exhibit several characteristics that are of particular significance to the discussion of the evolution of cultures. First, they present themselves as an *irreducible whole*. For such sets, if we limited our examination to some culturant subset of the whole, and, in many cases, if even just one culturant in the set is left out of consideration, the defining property of the set (that each constituent both receives as an input an aggregate product from another culturant in the set *and* produces an aggregate product that serves as an input into another culturant in the set, forming a feedback system) may not be observable. In such cases, defining boundaries according to arbitrary criteria may preclude a full understanding of the factors underlying the dynamics that are observed, as Mattaini (2004, 2006) anticipated. This irreducible wholeness also causes the system to respond in a nonlinear fashion to some external perturbances, one of the characteristics of self-organizing systems articulated by Mattaini (2006). In some cases, a relatively small perturbance at the boundary of the system may hinder or eliminate one of the culturants in the hypercycle, thus interrupting the dynamics of the entire cycle. On the other hand, if external changes, even large ones, do not disrupt the functional dynamics of the system, large changes at

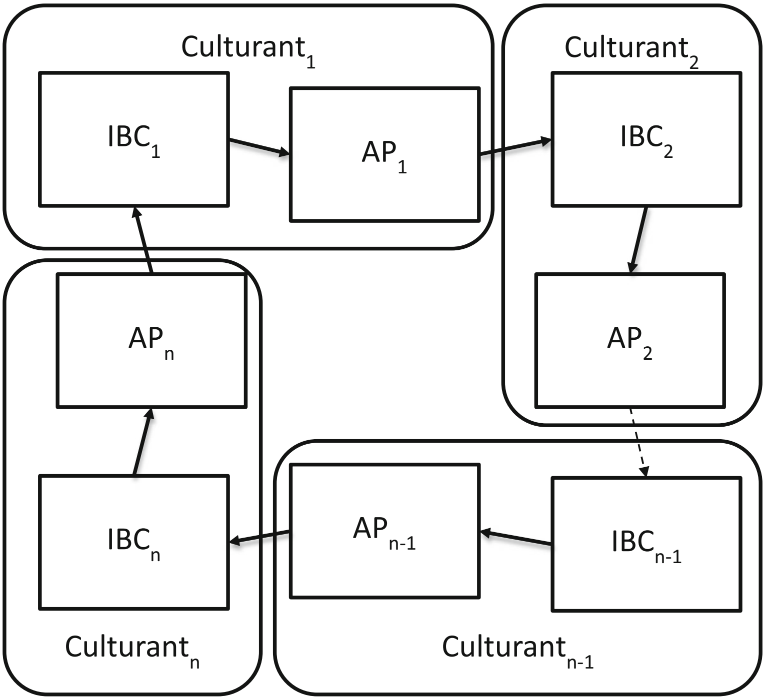

Fig. 1 The culturant hypercycle: in general form, IBC_1 produces AP_1, selected by IBC_2 that produces AP_2… selected by IBC_{n-1} that produces AP_{n-1}, selected by IBC_n that produces AP_n that is selected by IBC_1… As a result of the collective dynamics of the set, all of the culturants in the set are differentially selected as a set (group), promoting this group of practices over other practices that are outside of the set (between-group selection)

the boundaries of the system may not perturb the system at all, exhibiting what has been termed a homeostatic response (see Kauffman, 1993, 2000; Ulanowicz, 2009). It is in this manner that the dynamics within the system (the functional interactions), rather than external factors, determine the behavior exhibited by the system, fulfilling another of Mattaini's (2004, 2006) characteristics of self-organizing systems.

Second, the defining characteristics that enable an observer to distinguish the constituents of the set from those culturants present in the environment, but not included in the set, are based on *functional relationships*. Each culturant in the set serves the function of facilitating/enabling the occurrence of other culturants in the set, and is itself facilitated/enabled by other culturants in the set; culturants that do not satisfy these criteria are, by definition, not included in the set/system. It is in this manner that culturant hypercycles "construct" (or define) their own boundaries, fulfilling another of the characteristics of self-organizing systems.

Further, the functional interactions of the set result in another characteristic of the system, termed *centripetality* by Ulanowicz (2009). Centripetality is exhibited by a system when an increase in the selection of any one aggregate product in the set tends to flow through to the other members of the set, resulting in an overall increase for *all members*. It is the combination of irreducible wholeness and centripetality that are the key characteristics that define the culturant hypercycle as a between-groups selective process resulting in the *selection of cultures*. When a culturant hypercycle forms, the aggregate products involved (and the behaviors/practices that produce them) *collectively* gain an advantage not generated by any individual constituent, but rather based on their inclusion in the system *as a whole*. The selection of the aggregate product, AP_1, by a subsequent culturant, C_2, provides contingent, *within-group* consequences to the behaviors in the chain of interlocked behaviors that produced the aggregate product (C_1). In addition, any competitive benefit that its selection may provide to the aggregate product of the culturant (C_2) that selected it will create an increased demand for C_2 that will flow through the system until it results in an increased demand for the culturant (C_1) that produced the original aggregate product. This centripetality thereby changes the *contingencies of selection* for all products in the set. These products and practices are selected as a group (as evidenced by their collective increased rate of occurrence) over other individual products and practices, and compete against other sets of products and practices for available resources. This results in competitive dynamics *between groups*, consistent with this distinction as originally drawn Skinner (1981) and highlighted by Couto and Sandaker (2016). These products and practices, as a set, then both themselves serve as environmental settings for each other and for many other practices in their immediate surroundings, and also affect many other factors that play the role of environmental settings within the culture where such culturant hypercycles exist.

Couto and Sandaker (2016) labeled the second new process of selection that they described as affecting the evolution of cultures as *cultural selection.* In their conceptualization, cultural selection occurs when the environmental settings selected via the selection of cultures exert a reciprocal influence over the selection of other practices within the culture. We have already briefly mentioned above how the collateral consequences produced by culturant hypercycles may affect the conditions within which other practices occur, but there are other dynamics created by these systems that are worthy of note. The functional relationships among constituents of the set define its organization as a feedback system, and it is possible that the organization of the system may be conserved even if the particular constituents and structure of the set are changed. For example, we may consider a case where culturant $C_{outside}$, initially outside of the system, produces an aggregate product, $AP_{outside}$ that does a better job at facilitating the functioning of a culturant than does a similar aggregate product from another culturant within the set. In such a case, the aggregate product, $AP_{outside}$, may functionally replace that other aggregate product and be selected at a higher rate. If it also itself selects (and is facilitated by) the same aggregate product utilized by the original culturant, then it will functionally replace the original culturant in the set. This substitution of one culturant for another will change the particular structure of the set without substantively changing the overall functional organization of the system. This example illustrates how the system itself becomes a *selective process*, providing a context within which similar culturants may compete for inclusion in the set and may provide a particular process through which *cultural selection* may occur.

Now that the general form of a hypercycle has been described, we may readily identify other forms that these hypercycles may take in a cultural setting. Culturant hypercycles may also form when a culturant produces an aggregate product that serves as an establishing operation for the aggregate product of another culturant in the system *and* for which the aggregate product of another culturant in the system serves as an establishing operation for its own aggregate product. Further, operant hypercycles may form when a system of operants organizes, such that for each operant in the system the occurrence of the operant serves as either a reinforcer or an establishing operation for another operant in the system *and* for which the occurrence of another operant in the system serves as either a reinforcer or establishing operation for its own occurrence. In such an instance, the resulting increase in the rate of each operant in the system serves to *change the contingencies of reinforcement* for the other operants in the system, enriching the rates of reinforcement and further accelerating subsequent rates of occurrence for the operants in the set.

Behaviors and products in such culturant and operant hypercycles may interact across levels, forming complex, self-amplifying *culturo-behavioral hypercycles*. For example, Krispin (2017) described the autofacilitative effects present in the interactions between smart phones, and the applications that they run. In his example, cellular phone data networks and wireless connectivity, smart phones, applications, internet content (like social media content posted to websites like Facebook and Instagram) and social behaviors maintained by operant, social contingencies interact to form such a complex network.

Self-organizing systems display emergent patterns of organization/coordination that cannot be predicted from an isolated analysis of their constituents (Marr, 1996). These patterns exhibit structures of organization that are of a higher level (greater order) than that which preceded their emergence (Hudson, 2000). The culturo-behavioral hypercycles also display these characteristics. Although we may look at the included behaviors and aggregate products in isolation, and may even perhaps brainstorm an extensive list of functional characteristics that they display, we cannot possibly anticipate all of the ways that they may interact. Therefore, we cannot predict the particular structures that may emerge from these interactions (although it may often be evident in retrospect, i.e., 20/20 hindsight). Further, these systems may emerge with a minimal amount of (or even without) external interference and with "apparent spontaneity" as described by Hudson (2000, p. 551). In fact, in thermodynamic systems, such as those that we will discuss in some detail in the next section, *self*-organization, by definition, only occurs when it is accomplished using free energy available *within* the system (spontaneously). This self-organization may be contrasted with organizations that are formed from work done on the system by external forces. The changes in the organization of a system that result from external work performed on the system would, by definition, be nonspontaneous.

Differences between General Systems Theory and the Theory of Self-Organizing Systems

Our discussion to this point has centered on feedback as a foundational concept on which systems theories are built. In behavior analysis, feedback is typically defined as the provision of information regarding a behavior or its outcomes to the performer, forming one of the crucial processes at work in behavioral contingencies. In contrast, in GST, as in other systems theories including cybernetics (Ashby, 1957; Weiner, 1961) and system dynamics (Forrester, 1961, 1968; Senge, 1991), feedback is essentially defined in a more general sense as an iterative process where the outcomes of the cycling of a system become inputs/initial conditions for a future cycling of the system.

GST and TSOS both share this definition of feedback, despite coming from significantly different lineages. GST developed mainly from an interdisciplinary background, including inputs from engineering, computer science, and biology, for example. The principles of TSOS as outlined here stem from studies in thermodynamic, chemical and biochemical systems, specifically from the study of dissipative systems, which will be discussed in more detail shortly. In TSOS, although the same basic definition of feedback is accepted, the effects, particularly of positive feedback, have been found to lead to significantly different outcomes. For example, in GST, positive feedback, if left unchecked, will always have destructive effects. In TSOS, positive feedback may have significantly different effects, including the phenomenon known as self-organization. Much of the work that led to the definition of the conditions under which systems might exhibit such radically different behaviors as self-organization was done by Nobel-prize winning, Belgian thermodynamicist, Ilya Prigogine and his colleagues (Nicolis & Prigogine, 1989; Prigogine, 1961, 1980, 1996; Prigogine & Stengers, 1984) in their study of nonequilibrium thermodynamic systems. We will first present some of their findings before progressing to a discussion of how these findings may apply in the cultural realm.

One of the major factors causing the divergent understanding of systems and their behavioral patterns between GST and TSOS stems from the fact that in general GST limits its consideration to those that operate within what Prigogine and Stengers (1984) termed the *linear, near-to-equilibrium region.* In contrast, TSOS focuses primarily on systems that are operating in what they termed the *nonlinear, or far-from-equilibrium region*. For Prigogine and his colleagues, this differentiation between linear and nonlinear regions did not stem from the observed behavior of the system (GST uses nonlinear, differential equations to describe the behavior of the systems it considers). Rather, the distinction is based on the nature of the relationship between the forces that govern the behavior of the system and the corresponding fluxes (flows, or changes in behavior) that result from the forces. In TSOS, the systems of interest exhibit *nonlinear* changes in behavior in response to *linear* changes in the forces that are present; the relationship between the forces and fluxes present within the system is nonlinear. This may (but not necessarily) cause instabilities within the structure of the system, leading to the emergence of higher levels of organization.

Conditions for Self-Organization in Dissipative Systems

Prigogine and his colleagues (Nicolis & Prigogine, 1989; Prigogine, 1961, 1980, 1996; Prigogine & Stengers, 1984) termed the nonequilibrium thermodynamic systems that they studied *dissipative systems.* These systems are defined by their nonequilibrium state, characterized by the fact that these are systems in which energy is continually dissipated and entropy is produced. Dissipative systems exhibit *dissipative structures*. Simple examples of such dissipative structures include stable reactant/product ratios that may be sustained in basic chemical reactions in open systems. More complex examples of dissipative structures include vortices such as can be seen when water drains out of a basin, in the formation of tornadoes and hurricanes, and, on a much grander scale, in galaxies.

Prigogine and colleagues (Nicolis & Prigogine, 1989; Prigogine, 1961, 1980, 1996; Prigogine & Stengers, 1984) defined a number of conditions that were necessary for the self-organization of complex, dissipative structures of a higher order, and therefore lower entropy, than the structures from which they emerge. First, the system must be open, exchanging matter, energy, and/or information with its surroundings. Second, the system must be displaced some critical distance from equilibrium (in the nonlinear, far-from-equilibrium region). Third, the system must be nonlinear in the sense defined above (nonlinear relationships between forces and fluxes present within the system). Fourth (and the last condition that we will introduce), the nonlinearities within the system must *amplify* the effects of perturbances at the boundaries of the system and/or *amplify* local fluctuations from equilibrium within the system. This amplification process will accelerate the rate of change and production of entropy within the system. The derivation of these conditions is beyond the scope of what will be considered in the present article, but these conditions can be summarized in the following statement: Given a nonequilibrium, nonlinear thermodynamic system open to exchanges of energy and information with its environment, sufficiently displaced from equilibrium, and able to accelerate its rate of change through the amplification of perturbations and/or local fluctuations within the system, the spontaneous emergence, or self-organization, of a stable, complex organization of greater order and lower entropy (a dissipative structure), becomes possible.

Self-Organization as a Response to Perturbations at the Boundaries of a System

As we consider the role that the conditions outlined in the previous paragraph play in self-organizing phenomena, we will consider their effects first in systems containing what we will call *monoatomistic* constituents, then we will complexify the situation by similarly considering their effects in *combinatorial* systems. The term *monoatomistic* as we will use it here means that the constituents within a system only interact in inert ways—or, at least, that any deviations from this assumption are negligible in our analysis. In such cases, the typical interactions within these systems may be characterized by the kinetic interaction of constituents that may be modeled with classic "billiard ball" dynamics. Even in such systems, we may observe self-organizing phenomena when the conditions that Prigogine and colleagues (Nicolis & Prigogine, 1989; Prigogine, 1961, 1980, 1996; Prigogine & Stengers, 1984) outlined are present. In contrast, the term *combinatorial* as we will use it means that the constituents of the system may interact in other ways, forming combinations that have characteristics that cannot be anticipated based on the analysis of the individual constituents prior to combination. Such systems include, for example, systems within which chemical reactions are occurring, and behavioral systems in which we are more directly interested.

Let us first consider an example of self-organization in a thermodynamic system in which the constituents behave in a monoatomistic manner. We may illustrate this by articulating a simplified explanation of the formation of a hurricane. Hurricanes form in the presence of abundant moisture (supplied by evaporating water from the ocean), a thermal gradient (warmer air at the surface of the water and much cooler air high above the surface), the presence of gravity, and the rotation of the earth. In simple fluid systems, the interactions among particles may be modeled with billiard-ball dynamics. If we introduce a new condition, for example, the presence of a thermal gradient, we may still use billiard ball dynamics to model the dissipation of heat energy through the local interactions of molecules within the system—conduction. However, given a large enough thermal gradient, conductive dissipation will be supplemented with the convective, bulk motion of particles. In our weather system, a large enough temperature gradient (warmer near the surface of the water, and much cooler high above the surface) causes convective motion among the particles within the system when the effects of gravity interact with a corresponding pressure gradient produced among the particles by the temperature gradient. When the system reaches a certain critical distance from equilibrium, the relationship between forces and fluxes within the system changes from *linear* (conduction) to *nonlinear* (convection). In such situations, the denser, heavier, moisture-laden air that is higher up begins to displace the warmer, less dense, moisture-laden air that is closer to the surface of the ocean (warm air rises and cool air sinks), establishing a convective, vertical circulation. The vertical circulation begins to rotate around its vertical axis due to the Coriolis effect of the rotation of the earth, causing the counter-clockwise rotation of tropical cyclones in the northern hemisphere and the clockwise rotation of tropical cyclones in the southern hemisphere.

Prior to the self-organized emergence of the hurricane's structure, the interactions among the constituents may be characterized as *local*, readily described in spatial, temporal, and kinetic terms that are determined by the mass, velocity, and distances of the molecules and the duration of their individual interactions. After self-organization, the spatial, temporal, and kinetic descriptions become much more *long range.* In this case, the accelerative effects of gravitational attraction serve as a long-range, nonlinear force affecting all constituents within the system, interacting with the thermal and pressure gradients to create differential effects on the constituents. This leads to the macroscopic coordination of trillions of molecules and the emergence of a complex, dissipative structure that may last for weeks and may achieve macroscopic sizes measured in hundreds of miles.

In monoatomistic systems, self-organization may result in observable spatial and temporal dissipative structures that achieve scales that are macro in nature. However, the variety of states that these systems may achieve is relatively small due to limited degrees of freedom within the system. Now, let's extend this discussion to a world with which we are more familiar—the behavioral realm, where the resulting variety in the structures that may self-organize among functional interactions between behaviors and their products is much more diverse.

In our extrapolation from a monoatomistic system to a combinatorial, behavioral system, it is the differential effects of consequences on the behaviors that precede them that may create the nonlinear, accelerative effect required for self-organization. We may consider the set of all possible behaviors that a given organism may emit in this case as the constituents in our system under consideration. The selection of behaviors via operant selection serves to organize the distribution of behaviors in an organism's repertoire, causing the rate of some behaviors to accelerate and occur with a greater frequency than others (greater order, lower entropy distribution). The original matching law, for example, suggested that an organism's behavior will organize to proportionally match the benefits that accrue to each behavior displayed (Herrnstein, 1961). The distribution that results looks quite different than we might expect from a random distribution (lower order, higher entropy) of the behaviors in the repertoire of a given organism. The matching law demonstrates that, for behaviors, consequences serve as forces, whereas the rates and frequency of occurrence allow us to see the fluxes/flows that they create. However, although the relationship expressed in the matching law shows how consequences change the organization of behaviors, the relationship that it expresses reveals the *local* correspondence between force and flux (organization) for each individual behavior. In order to identify structures that form via self-organization, we must be able to see correlations and coordination *across and among* behaviors in the repertoire of an individual, or group of individuals.

Of course, the matching law adopts a molar perspective of behavior, and describes behavior that has achieved some dynamic equilibrium/steady state. If, however, we examine the dynamic relationship and pattern of response between a given behavior and the consequences that follow, then we may be able to observe and define schedules and/or patterns of reinforcement that may create the kind of nonlinear dynamics between force and flux required for self-organization (and which may not). For example (and this is purely speculative at this point), the lack of gross temporal variation in behavior governed by interval schedules of reinforcement (see Galbicka, 1992) may indicate that these schedules may not be able to create such dynamics. Further, Baum (1992) asserted that as response rates rise in variable interval schedules reinforcement rates cease to increase, leading to a feedback function that is negatively accelerated. Such negative accelerations are typical in the presence of negative feedback, not positive feedback. In contrast, ratio schedules typically result in a reduction in the interresponse times (IRTs), revealing an acceleration of the rate of responding that may satisfy one of the requirements of self-organization (although, by definition, the relationship between the occurrence of a behavior and the reinforcing consequences it produces is proportional). Although this increased rate of responding does not produce a relation between the IRT and reinforcement probability (see Baum, 2018), it does serve to reduce the time between reinforcing events. Further, schedules of reinforcement as developed for application in controlled settings mimic certain aspects of naturally occurring contingencies, but also differ from naturally occurring contingencies in ways that may limit the efficacy of this line of investigation. Given that self-organization is a dynamic and highly contingent phenomenon, identification of self-organizing phenomena in behavior may ultimately even necessitate adopting a molecular perspective on behavioral dynamics.

Various theoretical and research efforts within the realm of behavior analysis have uncovered numerous dimensions of the contingent relationship between operant response and reinforcement that create nonlinear dynamics. For example, the development of Behavioral Ecology of Consumption (BEC; see DiClemente & Hantula, 2003a, 2003b; Hantula, DiClemente, & Rajala, 2001; Rajala & Hantula, 2000) has demonstrated that hyperbolic discounting of the value of a reinforcer occurs when its presentation in relation to a behavior is delayed (see also Ainsle, 1992). Thus, this may function as a significant dimension that can produce nonlinear relationships between an operant (flux) and its consequences (force). Likewise, operant behavioral economic theory (see, for example, Hursh, 1984; Hursh & Roma, 2016) has opened new paths of investigation that might be relevant to the study of self-organization in behavioral systems. Operant behavioral economic research paradigms focus less on rates of behavior, broadening their perspective to instead focus on the relationship between effort expended by a subject and the corresponding consumption of reinforcers that this effort produces. This change in focus has led to the identification of factors that contribute to elasticity in the demand for reinforcers and has defined conditions in which a small change in the effort required to obtain a reinforcer may result in a large change in the amount of effort allocated to its acquisition.

With this context in mind, we may now expand our consideration to include the culturant and metacontingent selection. As Glenn (2004) described, when an aggregate product, produced via a chain of interlocked behaviors, is selected by a receiving system, consequences result that create differential, yet correlated and coordinated, effects on the rates of behaviors that may occur across individuals. Krispin (2016) observed that similar correlated and coordinated dynamics result upon the selection by a receiving system of a complex product produced by an individual. In such cases, these differential consequences may result in correlated, nonlinear, and accelerative effects on behaviors such that some chains of interlocked behaviors may themselves become recurrent. This will result in long-range correlations (greater organization and lower entropy) *across behaviors* that also look quite different than we might expect to see in the distribution of behaviors cumulatively displayed by individuals, even *after* we have considered the effects of naturally occurring and *local* reinforcers on individual behaviors.

Krispin (2016) argued that the processes of selection present within metacontingencies are not substantively different than operant contingencies. If this is correct, it would imply that the same characteristics in the operant–consequence relationship that lead to nonlinearities in behavioral systems would apply for metacontingencies. Self-organization in such systems may be possible under certain conditions. Long-range forces, such as the consequences resulting from selection of the aggregate product produced by the chain of interlocked behaviors in the culturant by a receiving system, must produce several effects. First, they must produce tracking consequences (as opposed to socially mediated, pliance consequences; see, for example, Hayes, Zettel, & Rosenfarb, 1989) that reinforce each and every behavior in the chain. Second, they must create similar dynamics and interactive effects among the behaviors in the culturant that we saw among constituents of our convective weather system due to the interaction between the pressure gradient and gravity. Some work within the realm of BSA, although not explicitly based on principles of self-organization, align quite closely with these criteria. For example, the work of Bill Abernathy (1996, 2000, 2008, 2009) to align incentives, available to every employee and indexed with organizational profitability, with organizational results produced by the processes within which they work provides a framework for providing tracking consequences that extend throughout the organization, and can lead to organizations that are "managed without supervision" (see Abernathy, 2000).

In contrast, many designed metacontingencies (like business processes; see Abernathy, 2009; Glenn & Malott, 2004; Malott, 2003) fail miserably at meeting these criteria. Although the selection of an aggregate product provides tracking consequences to the organization, the particular individual(s) that actually perform the behaviors in the chain of interlocked behaviors is(are) insulated from them. Many organizations put pliance consequences in place that are intended to support the tracking rules that they develop to articulate the relationship between the organization's output (its aggregate products) and its selection by receiving systems (customers). These pliance consequences are then administered by managers acting in accordance with these rules. However, this often results in the alignment of individual behaviors with local/pliance consequences without any consideration by the actor of the contribution that these behaviors have on the aggregate product or organizational tracking consequences. This type of approach would essentially limit the potential for the constituents within the organization to self-organize in response to the metacontingencies that are present.

Conclusion

We opened this article with a statement that summarizes the behavioral perspective, "Behavior is a function of its consequences" (Glenn, 2004, p. 134). Behaviors do not occur in isolation, they occur in open systems, where the performer is interacting with their environments, exchanging material and information. When a behavior occurs, it produces changes in its environment (consequences) that are correlated with the behavior and that have a functional effect on the behavior represented in the functional analysis inherent in the three-term contingency of operant behavior. Zeiler (1992) advocated that this perspective must also be supplemented with another, expanded definition of function. He defined the functional effects of behavior as not only the effects on the performer, but also on the surrounding environment, differentiating between immediate function and evolutionary function in the context of natural selection, stating,

> The terms *immediate function* and *evolutionary function* distinguish between current accomplishments and future effects on individual reproductive success or inclusive fitness. . . . Evolutionary function involves a genetic effect on numerous later generations, whereas immediate function are consequences now. (p. 419; emphasis in original)

Extending this distinction to the realm of behavior analysis, Zeiler (1992) asserted that the analysis of behavior focuses only on the immediate function of behavior, in particular on the effects that a given behavior has on its performer and also on the social and physical environment within which it occurs. As we have seen in our discussion of the metacontingency, these immediate effects, when created by selection of an aggregate product produced by a chain of interlocked behaviors, can create longer-range correlations and coordination across behaviors that may result in self-organization.

Zeiler (1992) observed that behavioral theories have struggled, even erred, however in reconciling immediate functional relationships with longer-term, evolutionary outcomes. He contended that, in the behavioral conceptualization, this was caused by confusion between causation and function. In defining the distinction between causation and function, he stated,

> Mechanism (causation) describes how outcomes are achieved. An evolutionary theory of causation based on the principle of natural selection might go as follows. Although selection is based on outcomes, it chooses mechanisms. When

> adaptive function is achieved, selection is for the causal mechanisms that produced it. (p. 423)

Zeiler cited optimal foraging theory as an example of the confusion between causation and function. He noted that many of the conclusions of these studies frame the discussion of the results in terms of fitness, survival, and other long-term outcomes (evolutionary functions), even when the data collected in the study essentially only considered behaviors and their immediate functions. Zeiler referred to optimal foraging theory as a specific example of an *optimality theory*. In general terms, he posited that optimality theories attempt to articulate a theory that defines what "optimal" behavior would look like, then compares observed behavior to the form predicted by this optimal model. This is done as a means of determining whether the hypothesized, optimal relationship is correct. He argued that such approaches are flawed because they ignore the fact that selective processes do not work on ideals, but rather on whatever is available.

As a replacement for optimality theories, Zeiler (1992) advocated for the adoption of a behavior systems approach. He observed that behavior cannot even be defined without reference to the context/environment within which it occurred, and, conversely, that environments do not exist without reference to the activities that occur within them. Therefore, there is no such thing as a standard environment, let alone an ideal one. Adoption of this perspective allows us to identify immediate functions of behavior (and its products) that extend beyond their effects on the performer to include their functional effects on other behaviors (and products) in the environment. This systems perspective also enables us to identify how the outcomes of one behavior may serve as inputs into other behaviors and behavioral processes. However, in order to fully integrate this expanded understanding of function, we must expand our definition of feedback beyond the standard, behavioral definition to include the broader understanding of feedback in systems theory.

With this broadened understanding of feedback, particularly when viewed through the lens of the theory of self-organized systems, our understanding of the broader dynamics at play in influencing behaviors, and even our understanding of new levels of selective processes, may be greatly enhanced. As we have seen, the immediate effects of behavior can result in operant hypercycles, where each behavior in the system both reinforces (or, more broadly, facilitates) another behavior in the system and itself is reinforced (or, more broadly, facilitated) by another behavior in the system. The resulting, interactive effects of such systems is that the collective acceleration of the behaviors in the system enriches the environmental settings and/or the contingencies of reinforcement for all behaviors in the system, creating a self-organized, positive feedback loop of behavioral interactions. Further, we have seen how culturant hypercycles link the immediate functions of aggregate products to create longer-term, evolutionary advantages to groups of culturants. This results in the enrichment of the contingencies of selection for all behaviors in the group and forms a process through which the selection of cultures may occur.

The lens of the theory of self-organized systems also enables us to define the niche for each culturant and identify the appropriate dimensions for defining the relative fitness of its aggregate product for that niche as compared to other available aggregate products in the environment. This forms the basis for a process of cultural selection that operates at a level above operant selection but also shapes the cultural practices that define a particular culture and distinguish it from other cultures. These processes, working together, link the immediate functions of behavior with the evolutionary functions to which they also contribute. Processes of selection operating at the cultural level are also based on outcomes of behavior, but the mechanisms that they select (the autofacilitative dynamics of practices involved in the culturant hypercycle) are quite distinct from the mechanisms selected at the behavioral level as Zeiler (1992) suggested.

TSOS also enables us to understand more fully the role of the metacontingency in cultural analysis. Originally proposed as a process of cultural selection that satisfied this level of selection as defined by Skinner (1953, 1981), the metacontingency now appears to be a process through which cultural practices are selected. But rather than fatally wounding the metacontingency, TSOS reestablishes it as central concept in a broadened model of cultural analysis. Although operant hypercycles play a role in these dynamics, their impacts are limited to situations where the behaviors included all occur in the same spatial and temporal instance. When we add aggregate products produced by behaviors, we introduce an element that allows for processes of cultural change to transcend this instance, allowing for cultural interactions that transcend the boundaries of immediate space and time.

Finally, although the broadened perspective of cultural change that has been presented in this discussion certainly expands upon the discussion of cultural change that has unfolded in circles of behavior analysis, the author does not believe that all processes of cultural change have been identified. A comprehensive model of cultural change and adaptation will almost certainly include additional processes that we have not yet anticipated. It is hoped, however, that the explication of the principles and concepts contained in this discussion will stimulate further discussion, uncovering even more avenues to explore as we continue to pursue a comprehensive, interdisciplinary understanding of the processes of change at work in the world around us.

References

Abernathy, W. B. (1996). *The sin of wages*. Atlanta, GA: Aubrey Daniels International.

Abernathy, W. B. (2000). *Managing without supervising: Creating an organization-wide performance system*. Atlanta, GA: Aubrey Daniels International.

Abernathy, W. B. (2008). Implications and applications of a behavior systems perspective. *Journal of Organizational Behavior Management, 28*(2), 123–138. https://doi.org/10.1080/01608060802100980.

Abernathy, W. B. (2009). *Walden Two* revisited: Optimized behavioral systems. *Journal of Organizational Behavior Management, 29*(2), 175–192. https://doi.org/10.1080/01608060902874567.

Ainsle, G. (1992). *Picoeconomics: The strategic interaction of successive motivational states within the person*. Cambridge, UK: Cambridge University Press.

Ashby, W. R. (1957). *An introduction to cybernetics*. London, UK: Chapman & Hall.

Baum, W. M. (1992). In search of the feedback function for variable-interval schedules. *Journal of the Experimental Analysis of Behavior, 57*(3), 365–375. https://doi.org/10.1901/jeab.1992.57-365.

Baum, W. M. (2018). Multiscale behavior analysis and molar behaviorism: An overview. *Journal of the Experimental Analysis of Behavior, 110*(3), 302–322. https://doi.org/10.1002/jeab.476.

Biglan, A. (1995). *Changing cultural practices: A contextualist framework for intervention research*. Reno, NV: Context Press.

Brethower, D. M. (1999). General systems theory and behavioral psychology. In H. D. Stolovitch & E. J. Keeps (Eds.), *Handbook of human performance technology: Improving individual and organizational performance worldwide* (pp. 67–81). San Francisco, CA: Jossey-Bass.

Brethower, D. M. (2008). Historical background for HPT certification standard 2, take a systems view, Part 1. *Performance improvement, 47*(2), 16–22. https://doi.org/10.1002/pfi.183.
Couto, K. C., & Sandaker, I. (2016). Natural, behavioral and cultural selection-analysis: An integrative approach. *Behavior & Social Issues, 25*, 54–60. https://doi.org/10.5210/bsi.v.25i0.6891.
DiClemente, D. F., & Hantula, D. A. (2003a). Optimal foraging online: Increasing sensitivity to delay. *Psychology & Marketing, 20*(9), 785–809. https://doi.org/10.1002/mar.10097.
DiClemente, D. F., & Hantula, D. A. (2003b). Applied behavioral economics and consumer choice. *Journal of Economic Psychology, 24*(5), 589–602. https://doi.org/10.1016/S0167-4870(03)00003-5.
Eigen, M., & Schuster, P. (1979). *The hypercycle: A principle of natural self-organization*. New York, NY: Springer.
Forrester, J. W. (1961). *Industrial dynamics*. Cambridge, MA: MIT Press.
Forrester, J. W. (1968). *Principles of systems*. Portland, OR: Productivity Press.
Galbicka, G. (1992). The dynamics of behavior. *Journal of the Experimental Analysis of Behavior, 57*(3), 243–248. https://doi.org/10.1901/jeab.1992.57-243.
Glenn, S. S. (1988). Contingencies and metacontingencies: Toward a synthesis of behavior analysis and cultural materialism. *The Behavior Analyst, 11*(2), 161–179.
Glenn, S. S. (2004). Individual behavior, culture, and social change. *The Behavior Analyst, 27*(2), 133–151. https://doi.org/10.1007/bf03393175.
Glenn, S. S., & Malott, M. E. (2004). Complexity and selection: Implications for organizational change. *Behavior & Social Issues, 13*(2), 89–106. https://doi.org/10.5210/bsi.v13i2.378.
Glenn, S. S., Malott, M. E., Andery, M. A. P. A., Benvuti, M., Houmanfar, R. A., Sandaker, I., Todorov, J. C., . . . Vasconcelos, L. A. (2016). Toward consistent terminology in a behaviorist approach to cultural analysis. *Behavior & Social Issues, 25,* 11–27. https://doi.org/10.5210/bsi.v.25i0.6634
Hantula, D. A., DiClemente, D. F., & Rajala, A. K. (2001). Outside the box: The analysis of consumer behavior. In L. Hayes, J. Austin, R. Houmanfar, & M.C. Clayton (Eds.), *Organizational change* (pp. 203–223). Reno, NV: Context Press.
Harris, M. (1979). *Cultural materialism: The struggle for a science of culture*. New York, NY: Random House.
Hayes, L. J., Dubuque, E. M., Fryling, M. J., & Pritchard, J. K. (2009). A behavioral systems analysis of behavior analysis as a scientific system. *Journal of Organizational Behavior Management, 29*(3–4), 315–332. https://doi.org/10.1080/01608060903092169.
Hayes, S. C., Zettel, R. D., & Rosenfarb, I. (1989). Rule following. In S. C. Hayes (Ed.), *Rule-governed behavior: Cognition, contingencies, and instructional control* (pp. 191–220). New York, NY: Plenum.
Herrnstein, R. J. (1961). Relative strength and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior, 4*(3), 267–272.
Houmanfar, R., & Rodrigues, N. J. (2006). The metacontingency and the behavioral contingency: Points of contact and departure. *Behavior & Social Issues, 15*, 13–30. https://doi.org/10.5210/bsi.v15i1.342.
Houmanfar, R., Rodrigues, N. J., & Ward, T. A. (2010). Emergence and metacontingency: Points of contact and departure. *Behavior & Social Issues, 19*, 53–78. https://doi.org/10.5210/bsi.v19i0.3065.
Hudson, C. G. (2000). From social Darwinism to self-organization: Implications for social change theory. *Social Service Review, 74*(4), 533–559. https://doi.org/10.1086/516424.
Hunter, C. S. (2012). Analysing behavioral and cultural selection contingencies. *Revista Latinoamericana de Psicología, 44*(1), 43–54.
Hursh, S. R. (1984). Behavioral economics. *Journal of the Experimental Analysis of Behavior, 42*(3), 435–452. https://doi.org/10.1901/jeab.1984.42-435.
Hursh, S. R., & Roma, P. G. (2016). Behavioral economics and the analysis of consumption and choice. *Managerial & Decision Economics, 37*(4–5), 224–238. https://doi.org/10.1002/mde.2724.
Hyten, C. (2009). Strengthening the focus on business results: The need for systems approaches in Organizational Behavior Management. *Journal of Organizational Behavior Management, 29*(2), 87–107. https://doi.org/10.1080/01608060902874526.
Kauffman, S. A. (1993). *The origins of order: Self-organization and selection in evolution*. Oxford, UK: Oxford University Press.
Kauffman, S. A. (2000). *Investigations*. Oxford, UK: Oxford University Press.
Krispin, J. V. (2016). What is the metacontingency? Deconstructing claims of emergence and cultural-level selection. *Behavior & Social Issues, 25*, 28–41. https://doi.org/10.5210/bsi.v25i0.6186.
Krispin, J. V. (2017). Positive feedback loops of metacontingencies: A new conceptualization of cultural-level selection. *Behavior & Social Issues, 26*, 95–110. https://doi.org/10.5210/bsi.v.26i0.7397.
Malott, M. E. (2003). *Paradox of organizational change*. Reno, NV: Context Press.
Marr, J. (1996). A mingled yarn. *The Behavior Analyst, 19*(1), 19–33.

Marr, J. (2006). Behavior analysis and social dynamics: Some questions and concerns. *Behavior & Social Issues, 15*, 57–67. https://doi.org/10.5210/bsi.v15i1.345.
Mattaini, M. A. (2004). Systems, metacontingencies, and cultural analysis: Are we there yet? *Behavior & Social Issues, 13*(2), 124–130. https://doi.org/10.5210/bsi.v13i2.20.
Mattaini, M. A. (2006). Will cultural analysis become a science? *Behavior & Social Issues, 15*(1), 68–80. https://doi.org/10.5210/bsi.v15i1.380.
Mawhinney, T. C. (1992). Evolution of organizational cultures as a selection by consequences: The Gaia hypothesis, metacontingencies, and organizational ecology. *Journal of Organizational Behavior Management, 12*(2), 1–26. https://doi.org/10.1300/J075v12n02_01.
Nicolis, G., & Prigogine, I. (1989). *Exploring complexity*. New York, NY: W. H. Freeman.
Prigogine, I. (1961). *Introduction to thermodynamics of irreversible processes*. New York, NY: Interscience.
Prigogine, I. (1980). *From being to becoming: Time and complexity in the physical sciences*. San Francisco, CA: W. H. Freeman.
Prigogine, I. (1996). *The end of certainty: Time, chaos, and the new laws of nature*. New York, NY: Free Press.
Prigogine, I., & Stengers, I. (1984). *Order out of chaos: Man's new dialogue with nature. Toronto*. Canada: Bantam Books.
Rajala, A. K., & Hantula, D. A. (2000). Towards a behavioral ecology of consumption: Delay-reduction effects on foraging in a simulated internet mall. *Managerial & Decision Economics, 21*(3–4), 145–158. https://doi.org/10.1002/mde.979.
Senge, P. M. (1991). *The fifth discipline: The art and practice of the learning organization*. New York, NY: Doubleday Currency.
Skinner, B. F. (1953). *Science and human behavior*. New York, NY: Free Press.
Skinner, B. F. (1981). Selection by consequences. *Science, 213*, 501–504. https://doi.org/10.1126/science.7244649.
Skinner, B. F. (1984). Author's response: Some consequences of selection. *Behavioral & Brain Sciences, 7*, 502–509. https://doi.org/10.1017/S0140525X00026984.
Skinner, B. F. (1988). Responses to commentaries. In A. C. Catania & S. Harnad (Eds.), *The selection of behavior: The operant behaviorism of B. F. Skinner* (p. 37). Cambridge, UK: Cambridge University Press.
Skinner, B. F. (1989). *Recent issues in the analysis of behavior*. Columbus, OH: Merrill.
Smith, G. S., Houmanfar, R., & Louis, S. J. (2011). The participatory role of verbal behavior in an elaborated account of metacontingency: From conceptualization to investigation. *Behavior & Social Issues, 20*, 122–146. https://doi.org/10.5210/bsi.v20i0.3662.
Ulanowicz, R. E. (2009). *A third window*. West Conshohocken, PA: Templeton Foundation Press.
von Bertalanffy, L. (1968). *General system theory*. New York, NY: George Braziller.
Weiner, N. (1961). *Cybernetics: Or control and communication in the animal and the machine*. London, UK: John Wiley & Sons.
Zeiler, M. D. (1992). On immediate function. *Journal of the Experimental Analysis of Behavior, 57*(3), 417–427. https://doi.org/10.1901/jeab.1992.57-417.
Zilio, D. (2019). On the function of science: An overview of 30 years of publications on metacontingency. *Behavior & Social Issues*. https://doi.org/10.1007/s42822-019-00006-x.

Affiliations

Jonathan Krispin [1,2]

✉ Jonathan Krispin
jvkrispin@valdosta.edu

1 Department of Management and Healthcare Administration, Valdosta State University, Valdosta, GA, USA

2 Langdale College of Business Administration, Valdosta State University, 1500 N. Patterson St., Valdosta, GA 31698, USA