Ecological Psychology, 25:316–326, 2013

ISSN: 1040-7413 print/1532-6969 online
DOI: 10.1080/10407413.2013.810107

Routledge
Taylor & Francis Group

Origins of Order in Joint Activity and Social Behavior

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How should we understand the origins of order and control that entail the systematic regularity of human behavior? Here, we address this question with respect to joint activity and social behavior via an explication of Guy Van Orden's formulation of interaction-dominant dynamics and his provocative discussion of the "blue collar brain." Using these 2 concepts we argue that human social behavior and performance is not controlled by a cascade of fast timescale activity (i.e., neural processes or individual action) but rather emerges from the modulated enslavement of faster timescale processes by much slower dynamical processes, such as shared task outcomes and socially defined historical context. We detail this argument by reviewing 2 recent behavioral findings that we believe provide evidence that the dynamics of human performance during a socially situated activity is interaction dominant. The first concerns the behavioral coordination that emerges during a novel joint-action collision-avoidance task. The second concerns the effects of stereotype threat on an individual's cognitive performance. Finally, we discuss how identifying the role that the slower timescale dynamics of social events and structures plays in shaping complex behavioral dynamics can guide future research on joint-action and human performance.

How should we understand the origins of behavior? What gives rise to the systematic regularity displayed during everyday human activity? Is it brain, mind,

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or neither? Is it a modular system of static cognitive processes, disembodied from body and environment, or a dynamic system of distributed, embodied, and embedded cognitive processes? If ordered human behavior is predicated on the latter, how should one conceptualize this organizational system? Is it open or closed, linear or nonlinear, hierarchical or heterarchical, or something else entirely? This dizzying array of questions reflects just a few of the thought-provoking issues Guy Van Orden forced us to consider. We do not pretend to be able to tackle all of these here. Rather, we list them as a set of challenges, a set of scientific demands that we feel should motivate the study of human behavior. Indeed, for us, it is these types of questions and the answers that Guy sought that shape our theoretical stance and research agenda.

Our interest predominantly lies in understanding the order observed during joint-action and social behavior. Here we consider two distinct aspects of such behavior, namely, shared movement goals and stereotype threat. The choice of these two very different social phenomena was deliberate in that we aim to show how the manner by which they influence behavioral performance is very similar. Our explanation draws inspiration from Guy's delineation of interaction-dominant dynamics and his insightful discussion of the blue-collar brain. The commentary here is therefore organized as follows: We first provide a brief introduction to interaction-dominant dynamical systems (IDDS) and outline Guy's argument that understanding human behavior from the IDDS perspective subjugates the brain to an enslaved blue-collar role. We then outline how these ideas provide a consistent way of understanding recent research investigating complementary social movement coordination and the effects of stereotype threat on cognitive performance.

INTERACTION-DOMINANT DYNAMICS

Guy embraced human behavior and cognition as neither localized nor linear but rather as an emergent and natural consequence of complex interactions and multiplicative processes that intricately bind body, mind, and environment. Like Guy, we take this to be self-evident and approach the understanding of ordered joint-action and social behavior from the fundamental assumption that all behavior is a self-organized property of an animal-environment system. Here *self-organization* is used to refer to behavioral order that emerges from the free interplay of system elements and processes (social or otherwise) rather than being dictated by a single process or executive controller. The argument that behavioral order is an emergent property of an animal-environment system is founded on the mutuality and reciprocity of an animal and its environment (i.e., animal and environment mutually and reciprocally affect one another across multiple temporal and spatial scales). This latter argument is a central tenet of the ecological approach to psychology, an approach Guy often promoted (e.g., Van Orden, 2002; Van Orden & Goldinger, 1994; Van Orden & Holden, 2002). A full discussion of animal-environment mutuality and reciprocity is beyond the scope of this article (see, e.g., Gibson, 1979/1986; Richardson, Fagen, Shockley, Riley, & Turvey, 2008; Turvey & Shaw, 1999, for a detailed discussion). For present purposes, however, it is enough to say that the mutual and reciprocal interactions that exist between an animal and its environment constitute a complex system of multidirectional constraint that operates at both fast and slow timescales to dynamically order and reorder behavior during the ongoing realization of behavioral goals (Stoffregen, 2003; Van Orden, Hollis, & Wallot, 2012; Warren, 2006). It is in this sense that the dynamics of human behavior are *interaction dominant.*

Consistent with the notion of self-organization, the time-evolving behavior of IDDS is soft-molded[1] and causally ordered by interactions between the elements, processes, and situational factors that comprise the system. These interelement and interprocess relations not only provide causal support for the self-ordered regulation of behavior by synergistically coupling system elements together into a coordinated whole but also adaptively alter the intrinsic dynamics and functional specification of the interacting elements, processes, and situational factors themselves (Anderson, Richardson, & Chemero, 2012; Kello, Beltz, Holden, & Van Orden, 2007; Van Orden, Kloos, & Wallot, 2009). This is in sharp contrast to hard-molded component-dominant dynamical systems in which system behavior is simply the product of fixed intrinsic dynamics and rigidly defined functions of system modules and components (i.e., a pendulum clock). Thus, if one were to examine the relationship between any two levels of IDDS, one would observe that the system elements or processes at the lower level modulate the macroscopic order at the higher level while at the same time are structured by the system's macroscopic order. To use an example that preempts issues to be discussed later, individuals at the microlevel, embedded within a macrolevel cultural system, modulate the behavioral order of the cultural system, while the dynamical organization of the cultural system simultaneously structures the behavior of the individuals embedded within it. IDDS is therefore a heterarchical system of circularly causal processes in which behavioral order emerges from relations that exist both within and among differing elements, processes, and levels of the system (see Figure 1b).

[1]A *soft-molded* or *softly assembled* behavioral system is a temporary coalition of coordinated entities, components, or factors organized around a specific behavioral goal. The term *synergy* is sometimes used to refer to softly assembled systems—a functional grouping of structural elements (molecules, genes, neurons, muscles, limbs, individuals, etc.) that are temporarily constrained to act as a single coherent unit (Kelso, 2009).

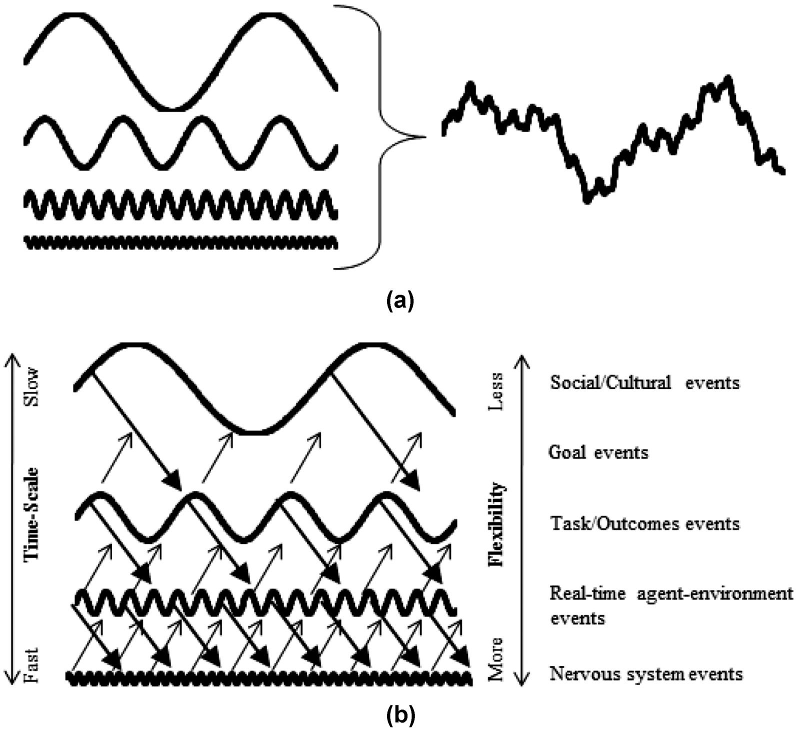

FIGURE 1 (a) Illustration of how different levels of organization or behavioral order are nested within a complex behavioral signal. (b) An illustration of the reciprocal and mutually defined system of interactional constraint that characterizes interaction-dominant dynamical systems. Note how the causal basis of behavioral order is circular, with the slower/larger amplitude processes operating to enslave the microorder of faster/smaller amplitude processes while at the same time the faster/smaller amplitude processes operate to modulate or perturb the macroorder of the slower/larger amplitude processes.

GUY'S "BLUE-COLLAR BRAIN"

This brings us to how behavior is "controlled" in IDDS. Over the last several years, Guy often argued (in both written work and verbal presentations; e.g., Van Orden, 2011; Van Orden et al., 2012) that IDDS involve different levels of temporal change—from faster microlevel fluctuations (noise) and state variable dynamics to slower parameter and graph dynamics (system architecture)—and that slower, larger amplitude levels constrain faster, smaller amplitude levels of change. In other words, although macroscopic levels of behavioral order emerge from the free interaction of microscopic processes, control generally operates from slow to fast in IDDS. A system's graph, for instance, is defined with respect to the configuration of system parameters and states and therefore must change more slowly in order to constrain the dynamics of system parameters and states. Similarly, system parameters are defined with respect to a specific configuration of state dynamics and therefore must change more slowly in order to constrain the dynamics of system states. In short, for one dynamic process to enslave the dynamics of another, the enslaver must change more slowly. Consequently, because fast timescale processes become defined by the dynamics of slow timescale processes, they are unable to directly control the dynamics of the slow timescale processes. Guy therefore argued, quite convincingly, that the fast dynamic processes of the nervous system are incapable of controlling the slower dynamics of observable human behavior and performance. Moreover, the brain cannot play an executive role in behavioral control and is thus subjugated to a *blue-collar* status (Van Orden et al., 2012).

It is important to appreciate that the aforementioned argument is not meant to imply that fast timescale processes cannot propagate throughout a system and are unable to influence global dynamics. Nor does it advocate a top-down approach to understanding the complex processes of human behavior. In the case of human movement, for example, fast timescale processes influence emergent states not through dynamic enslavement but rather through the body's tensegrity structure that acts as an excitable medium by adaptively altering constraints in order to sustain movement coordination (Van Orden et al., 2012). Similarly, self-organized states (the product of long timescale dynamics) often emerge near "criticality" in which small fluctuations (changes at faster timescales) result in adaptive stability (Bak, 1996). Indeed, it is the adaptive interactions that exist between system elements and processes that allow order to emerge rather than a specific set of feedback loops that integrate top-down and bottom-up mechanisms of control. Accordingly, one can think of long timescale activity as providing a framework of control for the short-timescale activity nested within the structure of IDDS.

UNDERSTANDING THE ORIGINS OF ORDER IN SOCIAL BEHAVIOR AND ACTIVITY

We argue that Guy's notion of the "blue-collar brain" can be extended to additional levels of organization and propose that social behavior and joint action involve a nested structure of blue-collar activity, including *blue-collar agents*. If the dynamics of human performance emerge from and enslave the dynamics of the brain in a nested structure that encompasses blue-collar agents, it follows that the dynamics of social and cultural processes must emerge from and enslave the behavioral dynamics of human performance. At a more fine-grained level, the behavioral dynamics of any real-time agent-environment behavior will be enslaved by the emergent dynamics of behavioral outcomes, which in turn are enslaved by the emergent dynamics of behavioral goals, which are defined and controlled within a continuously emerging social context (see Figure 1b). Note that this implies that behavioral control in social or joint-action IDDS is an emergent process that exists everywhere and nowhere at the same time.

To elucidate these ideas further, we review two recent behavioral findings that we believe provide evidence that the dynamics of human performance during a socially situated activity is interaction dominant. This first behavioral finding comes from a study investigating the stable patterns of movement coordination that emerged during a joint-action collision-avoidance targeting task (Richardson, Harrison, May, Kallen, & Schmidt, 2012). The second is a cognitive performance-based finding from a study investigating how an individual's math performance is influenced by stereotyped group membership (Eiler, Kallen, & Richardson, 2013).

Origins of Order in a Joint-Action Collision-Avoidance Task

A great deal of research has investigated the self-organizing dynamics of interpersonal movement coordination (see Schmidt & Richardson, 2008). The majority of this research, however, has only investigated these coordination processes using simple rhythmic coordination tasks in which pairs of individuals synchronize incidental rhythmic limb movements. To better understand the behavioral dynamics of more complex goal-directed joint-action tasks, Richardson et al. (2012) investigated the behavioral coordination that occurred between pairs completing a novel collision-avoidance task.

Pairs of participants ($N = 12$) were instructed to perform a repetitive targeting task in which they each moved a computer stimulus back and forth between sets of target locations without the stimuli colliding with each other. Each participant in a pair stood facing a 50-in. computer monitor and controlled the computer stimulus (a small red dot) using a motion-tracking sensor (see Figure 2a). targets were large squares positioned in each of the four corners of the monitor, with one participant moving the stimulus between the bottom-left and top-right target set and the other participant moving the stimulus between the bottom-right and top-left target set. Each monitor displayed the real-time motion of the participant's own stimulus as well as the motion of the co-participant's stimulus. Pairs received 1 point for completing a 40-s trial without colliding and the goal was to achieve a score of 15.

The results demonstrated that pairs converged onto a stable relative phase relationship of around 30°, with one participant spontaneously adopting and maintaining the role of "phase leader" and the other adopting and maintaining the role of "phase follower" (see Figure 2b and 2c). Of particular interest,

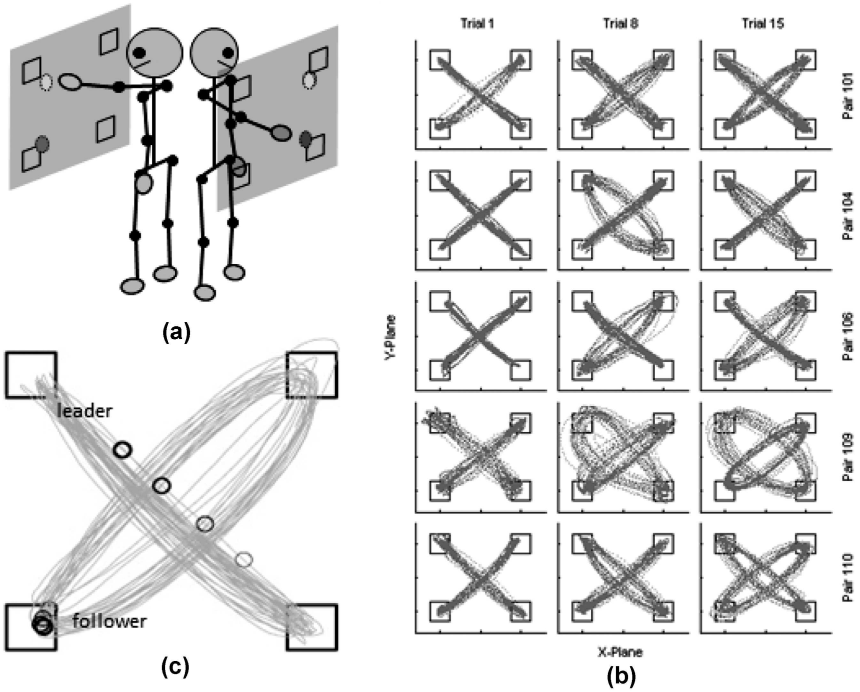

FIGURE 2 (a) Illustration of the experimental setup and stimulus displays used for the Richardson et al. (2012) rhythmic collision avoidance task. (b) Example movement data from Trials 1, 8, and 15 for five different participant pairs. (c) Descriptive illustration of the prototypical movement trajectories exhibited by phase leader and phase follower. Circles illustrate relative positions of phase-leading and phase-following participant. See text for more details.

participants who adopted the role of phase leader tended to exhibit more of a straight-line trajectory between targets, whereas participants who adopted the role of phase follower tended to exhibit a more elliptical trajectory. That is, participants spontaneously adopted complementary task roles by relaxing and recruiting different movement degrees of freedom. If pairs attempted to move identically (i.e., both tried to move using an equally straight or elliptical trajectory) they nearly always collided or had to perform the task very slowly. They faced a conflict between the natural tendency to synchronize their movements inphase and the fact that such synchronization would result in a collision. Interestingly, it was asymmetry in participant movement patterns that enabled pairs to overcome this conflict. Essentially, participants learned that adopting different movement trajectories introduced a spatial-temporal phase lag into the coordination and this phase lag enabled them to avoid collisions without fighting the attraction toward synchronization.

For this novel collision-avoidance task, all pairs discovered a stable collective joint-action organization that achieved successful performance and that was not reducible to the movements of either individual. It is important to note that pairs discovered the stable organization implicitly—they were not aware of the low dimensional dynamics that emerged, nor could they articulate how collective organization was controlled. Moreover, this globally stable joint-action behavior emerged from the fluctuations that occurred during the interaction of their movements. Close calls and near misses perturbed participants' movement in a way that revealed the stable task solution. Moreover, the control of "who-did-what-and-when" emerged over trials, rather than within a trial, and was determined by the dynamics of trial outcomes with respect to the task goal. The emergent subroles operated to control the future real-time activity of participants. Indeed, the persistence with which participants adopted a specific role within and across trials provides evidence of how an emergent social structure can enslave the behavioral organization of individuals. In this case, individual participants were blue-collar workers with respect to joint-action control, with participants' real-time movement dynamics dominated by their interaction and collectively controlled by the slow-timescale dynamics of the interpersonal configuration that defined task success. A provocative possibility is the global persistence of this joint-action IDDS, whereby emergent roles permeate to other movement or social tasks, instantiating an asymmetric structure of leadership or rapport that controls the future activity of the pair.

Social Origins of Order in a Simple Reaction-Time Experiment

Human behavior is embedded within situational and cultural context (Coey, Varlet, & Richardson, 2012; Richardson, Marsh, & Schmidt, 2010). Even for tasks considered predominantly cognitive, such as academic performance, context influences behavioral outcomes. Research has clearly demonstrated that academic performance results from complex interactions between dispositional and situational factors for members of stigmatized groups (see Steele, Spencer, & Aronson, 2002, for review). Specifically, Steele and colleagues proposed that negative group stereotypes regarding ability exist "in the air" and can help to explain how African Americans and women underperform on measures of intellectual or math ability when compared with majority group members (e.g., Steele, 1997). This phenomenon, known as stereotype threat, is proposed to interfere with cognitive functioning when performance in the stereotyped domain is self-relevant and has the potential to confirm negative stereotypes regardless of self-perceptions about ability or beliefs about the validity of stereotypes. In short, situational factors contain information about cultural beliefs and exert a negative influence on performance at the cognitive level. A major shortcoming in our current understanding of the negative effects of stereotype threat is the lack of a clear process by which the socially constructed stereotypes produce differential performance outcomes during situated cognitive activity. 1/f scaling behavior is a hallmark characteristic of IDDS. The presence of 1/f scaling behavior during cognitive tasks has consequently been taken as evidence in support of the claim that the dynamics of cognitive performance are interaction dominant (Van Orden, Holden, & Turvey, 2005; Van Orden, Moreno, & Holden, 2003). Eiler et al. (2013) have proposed that stereotype threat-induced performance differences are a consequence of the slow timescale dynamics of cultural beliefs, in this case stereotypes, enslaving faster timescale dynamics of cognitive performance and activity.

To test this hypothesis, Eiler et al. (2013) manipulated stereotype threat (by either invoking the stereotype that women are less capable at math than men or by stating no differences by sex exist) during a simple reaction time task in which male and female participants ($N = 128$, 41% male) were required to categorize strings of numbers as prime or nonprime by pressing a key on a keyboard as quickly as possible. Reaction time (RT) latencies were transformed into 512 ($n = 87$) or 256 ($n = 41$) point time series and subjected to detrended fluctuation analysis to estimate the fractal dimension (Hurst). Hurst values were also calculated for randomly shuffled surrogate time series. For each condition and gender the mean Hurst calculated from real data was significantly greater than the Hurst calculated from surrogate data, indicating that the RT performance of participants in all conditions was scale invariant (i.e., fractal). More important, women tended to produce greater levels of individual differences compared with men and overall "whiter" levels of performance, suggesting that the stereotype can have an overall negative effect on the long-term structure of performance (Eiler et al., 2013). It is possible that this study simply establishes that women are more random on this task and that whiter levels of performance are not due to the invoked stereotype but are due to some other confound, like effort, which has also been shown to produce more random variation in performance when stereotypes are primed (Correll, 2008). The authors are currently conducting additional studies to clarify the origin of this order in performance.

These results are the first to investigate the dynamic structure of performance under stereotype threat and are consistent with previous empirical evidence suggesting that stereotypes affect human performance by imposing additional constraints that enslave the dynamics of cognitive activity. The fact that stereotype threat is generalizable to noncognitive domains like athletic ability (Beilock & McConnell, 2004; Stone, Lynch, Sjomeling, & Darley, 1999) suggests that the underlying governing principles may reflect slower social processes not specific to the fast dynamics of cognitive and neural events. Because slower timescale dynamic processes drive macroscopic order by enslaving faster processes, the

IDDS approach leads to the a priori prediction that standardized test performance is disproportionately constrained and controlled by slower cultural dynamics, where fast timescale cognition plays a subordinate blue-collar role. Simply put, the IDDS model of stereotype threat-induced underperformance proposes that cultural and historical context are coupled to socially situated cognition and action and exert influence on moment-to-moment behavior by enslaving the fast temporal dynamics of socially embedded processes of cognition and action.

CONCLUSION

In this article we have attempted to show how two ideas synonymous with Guy Van Orden, namely, *interaction-dominant dynamics* and the *blue-collar brain*, reveal the origins of order in two very distinct examples of socially situated behavior. These ideas have significantly shaped our approach to understanding and investigating social behavior. Most important, they motivate our contention that because all human behavior is embedded within a social context, identifying the role social constraints play in shaping complex behavioral dynamics is essential for elucidating the origins of order in human performance. We have no doubt that these ideas, as well as Guy's collective body of work, will continue to influence us in the future. We also believe that Guy's work will continue to shape the thinking of many others and that his legacy will emerge from his instrumental role in forging new methodological and theoretical advances in the general fields of cognitive science and psychology.

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