© *Academy of Management Review*
2015, Vol. 40, No. 2, 263–290.
http://dx.doi.org/10.5465/amr.2013.0273

A QUANTUM APPROACH TO TIME AND ORGANIZATIONAL CHANGE

ROBERT G. LORD
JESSICA E. DINH
Durham University

ERNEST L. HOFFMAN
University of Akron

Prevailing perspectives on time and change often emphasize the forward movement of time and the relative stability of attributes, an emphasis that fosters theories of organizational evolution as a linear progression of a past that moves to the present that moves to the future. While useful in many respects, this perspective obscures the uncertainty of emerging organizational phenomena, and it offers little insight into the rare and unpredictable events that change the course of history. To address these concerns, we draw on quantum mechanics and quantum probability theories to present a quantum approach to time and change as a framework for understanding organizational complexity and the common decision-making errors that lead to organizational failures within uncertain environments. This perspective also explains how organizations (or societies) can experience unforeseen potentialities that radically change their development by conceptualizing the future as existing in a state of potentiality that collapses to form the present based on the dynamics of system constraints. Our theory has broad implications for organizational theory and research, as well as management practice.

> You can never plan the future by the past (Edmund Burke).
>
> Learn from the past, set vivid, detailed goals for the future, and live in the only moment of time over which you have any control: now (Denis Waitley).

In the last two decades organizational scholars have recognized the importance of time in understanding organizational processes (Ancona, Goodman, Lawrence, & Tushman, 2001). In fact, the ability to control various aspects of time, such as the structure of time, the subjective experience of time, how one thinks about time, and the entrainment of events through time (Bluedorn & Jaussi, 2008; Sonnentag, 2012), is thought to underlie effective leadership, group, and organizational dynamics. However, perhaps the most important issue for individuals and organizations is to devise ways to control their future, and this is related to how we conceptualize and use time.

Time can be measured objectively, but it is the subjective and intuitive aspects of time that may be most critical in understanding how time relates to organizational processes. Subjective time is central to individual sensemaking (Hernes & Maitlis, 2010) and cultural sensemaking (Zerubavel, 2003), which use both cognitive and emotional schema to connect (or separate) even the distant past to (from) the present and create anticipated trajectories leading to the future. Intuitive processes provide a basis for understanding the flow of time as a feed-forward process, where the past flows into the present and then into the future. This conceptualization of time is a generalization from how one physically moves through one's physical environments, such as moving forward from one's present location to another location. It also reflects the structure of human memory systems, which use remembered experiences (i.e., episodic memory) as a basis for projecting into the future (Kaplan & Orlikowski, 2013; Suddendorf & Corballis, 2007).

Because we understand change and adaptation in terms of a subjective flow from the past to the present, we naturally conceptualize the future as an extension of ongoing longitudinal

We thank Jerome Busemeyer, Mark Hall, Paul Hanges, Gerald Hodgkinson, Julian Marewski, Aron Polos, and three anonymous reviewers for helpful comments on previous drafts of this manuscript.

trajectories, guided by an evolution from the past to the present and extending to the future. This view supports individual and collective sensemaking (Ibarra & Barbulescu, 2010; Weick, 1995), and when the future departs substantially from this trajectory, organizational scholars, as well as managers, are motivated to explain it and build relevant theory. However, organizational scholars have increasingly recognized that discontinuous change cannot be anticipated easily from a narrow focus on the events that occurred in the present or the past (MacKay & Chia, 2013; Plowman, Baker, Kulkarni, Solansky, & Travis, 2007). In fact, the world often changes in ways that are unforeseeable and not easily anticipated (Taleb, 2010), since it involves the emergence of new states (e.g., movement from despair to optimism, from munificence to scarcity, from failure to success), new capacities (e.g., skills, creativity, adaptability), and new resources (e.g., social capital) that previously did not exist or had no comparable analogue. Such unanticipated change tends to be explained in terms of the functioning of complex systems (Uhl-Bien & Marion, 2009) or, alternatively, as a consequence of turbulent environments characterized by "relentless chance, environmental circumstance, and unintended consequences" (MacKay & Chia, 2013: 221).

In this article we develop a different perspective on time and the nature of individual and organizational processes, which, we argue, has great relevance to the issue of how futures unfold and can be influenced. We propose that the challenges of understanding organizational futures and the dynamism of unfolding events over time can be addressed, in part, by undoing the dominant tendency to view a forward flow of time based on a past that leads to the future (i.e., past → future). Instead, we advocate efforts to *mentally* reverse the arrow of time to emphasize a future that flows into the present (i.e., future → present), which is a view that has not received sufficient attention (e.g., Kaplan & Orlikowski, 2013). Perceptually, this shift is analogous to being in a train looking out the window and seeing the distant horizon flow toward one's present location, even though one knows it is the train that is moving toward the horizon.[1] We maintain that this mental reversal of a basic assumption guiding organizational science and intuitive reasoning can help us overcome limitations from commonsense beliefs about development and causality (Sherover, 2003) and narratives that connect the past to the present (Taleb, 2010). The future offers many *potentialities*, which we define as alternative states and possible outcomes that could occur but have not yet occurred because, to be actualized, they require the enactment of individual, social, and environmental events that are often serendipitous.[2] As such, many sets of unrealized potentialities (also referred to as a *superpotentiality state* in quantum theory; Greene, 2004) cannot be easily envisioned or pursued from a perspective that begins by considering the present or past. Rather, they can be better appreciated by starting with an unconstrained future with many possible outcomes and realizing that its flow into the present can be influenced by many individual, collective, and environmental factors that guide unfolding, organizing processes.

We maintain that this perspective has a natural affinity to *quantum probability theories* derived from quantum mechanics (Greene, 2004, 2011), which also begin with an undefined state, and it offers an innovative approach for understanding the unfolding of complex organizational phenomena. Although this approach to understanding process can be seen as a far cry from those advocated in the social sciences, we note that the application of quantum theories to social phenomena is not entirely foreign, having been applied to early philosophical teachings on general existence and the state of being (see Bakken & Hernes, 2006, and Epperson, 2004, for a summary of Alfred North Whitehead's process philosophy). However, because the focus and contribution of our article is not to elaborate on these existential or philosophical considerations, we direct readers interested in these issues to other sources (see Bakken & Hernes, 2006; Epperson, 2004; Whitehead, 1978).

[1] We thank an anonymous reviewer for suggesting this perceptual analogue of our reasoning.

[2] We note that potentialities are similar to affordances, which Gibson (1986) defined as possibilities that exist in one's environment and that become available upon action. However, potentialities refer to a more general state containing a set of undefined alternative outcomes that exist simultaneously and that become defined only upon enactment in a specific context.

In developing our perspective, we extend theories that were developed over the course of a century in the physical sciences but have not yet been considered sufficiently by organizational science. We maintain that by integrating quantum theory with a view of the future as flowing into the present, we can revolutionize our conception of the processes linking time to the development of events, offering the potential for greater understanding and perhaps greater control of the future, as well as an enhanced understanding of change processes.

This combined approach, which we label a *quantum approach to time and change* (QATC), has at least three principal advantages. First, a QATC provides a novel perspective for theory building in organizational science by emphasizing that the future is often qualitatively different from the present or past. As such, it provides an understanding of dynamic organizational phenomena, considering how organizational life, and life in general, can change by developing in many different ways as individuals and collectives interact with their environment. Quantum theory can represent multiple interacting paths through time and, thus, can represent the complexity of change in ways that more conventional models cannot (e.g., Markov models; see Busemeyer & Bruza, 2012).

Second, a QATC is grounded in quantum physics, which offers a diverse set of research tools and concepts that could supplement existing tools for studying dynamic change in organizations. It has the potential to build on insights provided by qualitative, process-oriented descriptions of organizational change that emphasize the role of context in guiding organizing processes (see Langley, Smallman, Tsoukas, & Van de Ven, 2013), while simultaneously developing a precise conceptual and mathematical representation for incorporating context into predictions of outcomes.

Third, many of the ideas that we address challenge fundamental assumptions regarding the nature of change that have guided organizational science. Such assumptions operate at the level that Alvesson and Sandberg (2011) have characterized as field assumptions because they undergird entire fields of study. These include the assumptions that (1) time should be conceptualized as flowing from the past to the future, (2) future states can be reached from paths grounded in the past and in existing practices, and (3) phenomena of interest (e.g., personality, attitudes, values, cultures, strategies) exist independent of our attempts to measure them. We did not set out to challenge such assumptions but, rather, gradually realized that questioning such taken-for-granted assumptions helped us understand organizational and psychological processes in new and useful ways. Our hope is that explicitly acknowledging this issue at the outset will help readers in a similar manner.

In the following sections we begin by explaining our natural understanding of time and compare this with a very different understanding of the unfolding of actual experiences and events brought forth by quantum theories. Finally, we address the theoretical, methodological, and practical implications of a QATC for organizational science.

TIME, ORGANIZATIONAL SYSTEMS, AND UNCERTAINTY

Commonsense Approaches for Understanding the Flow of Time

Unique to humans is the striking ability to travel through time, psychologically departing from the present to consider events in the future (Buckner & Carroll, 2007; Kaplan & Orlikowski, 2013; Sherover, 2003; Suddendorf & Corballis, 2007). Individuals frequently traverse the temporal boundaries of the present to consider the glimmering hopes and dangers hidden in the future (Dane & George, 2014). The advantage of these mental activities is that they allow one to forecast what the future may be based on one's prior experiences and intrinsic desires (Dane & George, 2014; Seligman, Railton, Baumeister, & Sripada, 2013). It can also assist in forming social inferences, anticipating the intentions and beliefs of others (Buckner & Carroll, 2007), and formulating one's own expectations and goal-directed behavior (Seligman et al., 2013). The ability to accurately forecast the future is so critical that humans have developed extensive neural networks dedicated to the storage, access, and integration of existing memory in order to simulate the possibilities that may arise tomorrow (Gilbert & Wilson, 2007). Indeed, it may be humans' natural ability to forecast that has created a strong cognitive tendency to formulate decisions and behaviors based on a forward-moving perspective of the future. This tendency also has been reinforced by social-cultural development and learning (i.e., the future as moving forward; Boroditsky & Ramscar, 2002), and it is a trend that is central to many of today's organizational theories and research paradigms.

However, there are many cognitive fallacies that accompany prospective assessments of the future (Dane & George, 2014; Seligman et al., 2013). They occur as humans form erroneous assumptions based on what has occurred while neglecting what *may have* occurred. In such instances prospective errors can manifest as forecasting biases that unduly influence decision making and behavior in ways that fail to account for the uncertainty and nonlinearity of realistic organizational events (Arrfelt, Wiseman, & Hult, 2013; MacKay & Chia, 2013). Several examples demonstrate this. For example, the bankruptcy of several American automobile companies (e.g., General Motors, Chrysler) in 2009 illustrates the culmination of global market conditions and the failure of organizational decision makers to forecast changing consumer preferences for more fuel-efficient vehicles. Forecasting biases also manifest in everyday decision-making errors, such as in the tendency to make optimistic self-predictions with respect to saving money or future performance (Helzer & Dunning, 2012; Koehler, White, & John, 2012), and in hindsight biases where accurate projections are inhibited because of limitations in one's ability to objectively remember prior information.

In brief, a wide body of research suggests that although there is a biosocially grounded tendency for humans to infer the future by extending the past, prospective cognitions are susceptible to processing failures because they are often based on salient nonrepresentative memories and experiences and are made in abstraction without reference to context (Dane & George, 2014; Gilbert & Wilson, 2007). As described in the following section, there are many advantages in considering an alternative view of the flow of time.

An Alternative Conceptualization of Time and Organizational Uncertainty

Organizational events and events occurring within individuals manifest very differently at different points in time (Hoffman & Lord, 2013), even though there is a tendency for humans and societies to subjectively represent time in ways that create a sense of consistency (Hernes & Maitlis, 2010; Zerubavel, 2003). For example, individual cognitive, emotional, and physical states all have inherent rhythms and dynamics that vary across time and context (e.g., hunger, fatigue, boredom, lust, circadian rhythms), and these interacting systems create different contexts that allow different thoughts and individual behaviors to emerge (Dionysiou & Tsoukas, 2013; Read et al., 2010). Similarly, complexity theories have been used to describe the behaviors of groups and organizations (Uhl-Bien & Marion, 2009), which are understood to fluctuate rapidly and often unpredictably (e.g., Crawford & LePine, 2013; Klarner & Raisch, 2013; Langley et al., 2013) as contexts change and as organizational processes take on different features or forms. Yet variations across time within individual and organizational systems are typically ignored because of theoretical or methodological oversights (Kozlowski, Chao, Grand, Braun, & Kuljanin, 2013; Vancouver & Weinhardt, 2012), obscuring the richness of organizational phenomena. Variations are also ignored because they are seen as errors, rather than resulting from phenomena that should be explained scientifically.

However, qualitative research has demonstrated the complexity inherent in organizational systems and the need for more adequate explanatory systems. For example, Plowman et al.'s notable study (2007) described how a culmination of seemingly small events and existing preconditions at a dying institution, Mission Church, helped radically shift the organization's structure and image. Specifically, they described how a small event (i.e., a meeting of five to six relatively inactive churchgoers to organize a charity event) initiated a chain of events that disrupted existing patterns of behavior within the organization and the community, thereby encouraging innovation and the reinvention of the church. Importantly, high uncertainty, defined as the inability to accurately predict outcomes resulting from the lack of information (Milliken, 1987), accurately characterizes Mission Church's change, as well as the change trajectories of many of today's organizations (see MacKay & Chia, 2013). In fact, for many organizations the strategic allocation of resources to nurture high-potential business subsidiaries is challenging simply because organizational decision makers cannot foresee the market conditions, economic trends, and societal factors that may aggregate to impact the survival of one subsidiary over another (Arrfelt et al., 2013). Such observations reinforce our arguments that events unfold probabilistically in the future in ways that forward-based prospection cannot explain.

Meanwhile, for almost a century the field of quantum physics and quantum mechanics has been able to model the complexity and uncertainty in the movement of various entities, including subatomic particles and the universe, by using an intensively scrutinized mathematical formalism (Greene, 2004, 2011). We believe that this way of thinking and representing processes can be extended to understanding how human systems construct the future. In the following sections we describe our QATC perspective, which implies that real-life organizational processes follow a different logic in the flow of time, a different set of probability laws, and a mathematical formalism based on quantum mechanics that can better account for complexities endemic to human and organizational systems.

A QATC

Quantum Physics and Probability Wave Functions

Quantum physicists describe a fundamental property of matter and energy, which is that they seem to have both particle and wave properties (e.g., light and magnetism; Feynman, Leighton, & Sands, 2010/1965; Rae, 2005). For example, electrons appear to travel across time and space not as specific particles with precise trajectories but as *waves* that occupy multiple locations. This is because the precise location of an electron is generally unknown, and it can appear in an infinite number of places in space upon measurement (Greene, 2004). As such, the movement of an electron through space is better represented by a "smeared" trajectory, rather than a single line that would indicate a predictable trajectory as used in classical probability theory (see Figure 1).

More precisely, the variable movement of an electron through space can be depicted mathematically by abstract, algebraically derived *probability wave functions* (i.e., mathematical representations of likely possible outcomes), shown graphically as waves that indicate where the electron should be at a particular point in time. Such a probability wave is shown in Figure 2. In this figure the probability of finding an electron at a particular position increases with the height of a particular hill compared to the surrounding plane. Central to this figure is that probability waves are characterized by a high degree of uncertainty in knowing where an electron will be when it moves through space. However, when a physicist mea-

FIGURE 1
Comparison Between (a) Classical Probability Theory and (b) Quantum Probability Theory for Representing the Predicted Outcomes of Physical and Psychological Phenomena As They Travel Across Time

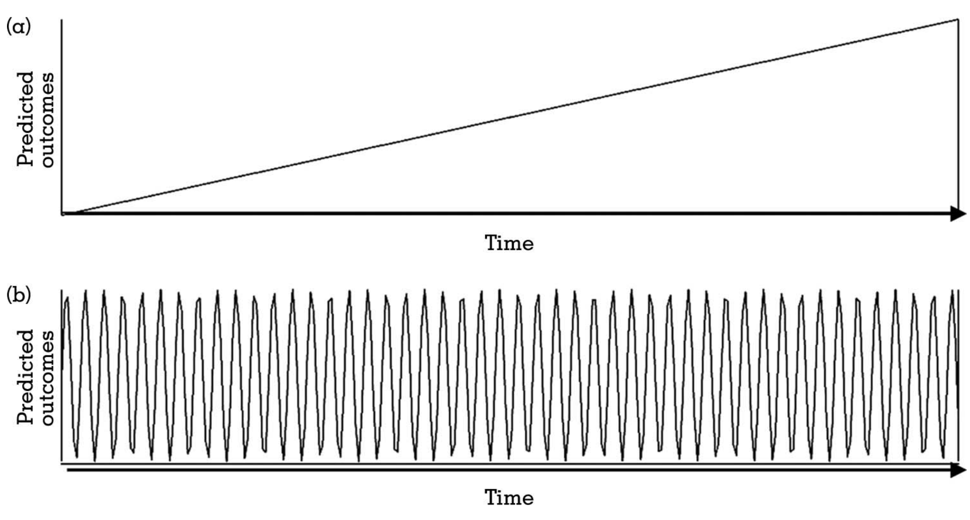
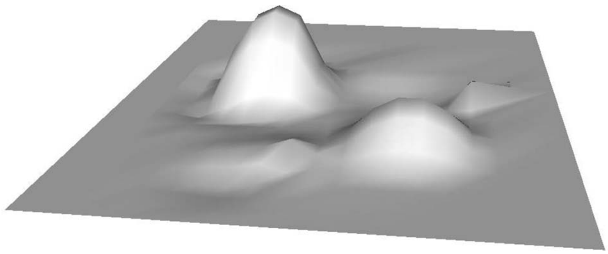


FIGURE 2
Probability Wave Function of an Electron Traveling Through Space



Note: The probability of an electron being at any position is proportional to the height of the wave at that point.

sures an electron's position, constraints imposed by the measurement process cause its probability wave to collapse, allowing the physicist to depict the electron at a specific, single location. This phenomenon may also be observed when organizational scholars measure constructs at one or multiple discrete points in time, where measurements are subject to constraints inherent in the measurement tools they use (Feldman & Lynch, 1988; Harrison & McLaughlin, 1996). This explanation accounts for why there is higher certainty in knowing exactly where an electron is, or what organizational constructs are, upon measurement than prior to measurement (Feldman & Lynch, 1988; Greene, 2004; Harrison & McLaughlin, 1996).

The principles of quantum theory have broad applications beyond the domain of subatomic particles. Recently, they have been applied to understanding the influence of context on decision making and the creation of cognitive concepts (Busemeyer & Bruza, 2012; Busemeyer, Pothos, Franco, & Trueblood, 2011; Gabora, Rosch, & Aerts, 2008), to understanding the creation of consciousness and how individual cognitive processes change over time (Hameroff & Penrose, 2014), and to theorizing regarding the existence of alternate realities that parallel our own in the universe (see Greene, 2004, 2011). These applications not only demonstrate the robustness of quantum mathematics for modeling diverse phenomena (Greene, 2004; Pothos & Busemeyer, 2013) but also suggest that future psychological and physical phenomena do not emerge from a single past. Rather, they are selected from an infinite set of potential realities that are best represented by probability waves. In the following sections we describe the key arguments of quantum theories and develop their theoretical application to organizational science. We also describe the mathematical formalism of quantum theories in the Appendix.

Probability Waves and Social Systems

Using probability waves as a metaphor for organizational processes, we propose that the amount of certainty in knowing *where* a particular particle is located at a point in time can be generalized to understanding how social systems create a specific, experienced reality at a particular point in time when they, too, are guided by processes that are functionally represented by probability waves. This reasoning suggests that there are many possible outcomes that can be represented and enacted since the future exists in a state with many potentialities. Quantum physics defines such a state as a *superpotentiality* (or superposition) state, in which many possibilities are in an indefinite state but have the potential to occur when influenced by a specific context. However, when conjoined with a particular context, this superpotentiality state will collapse because of experienced constraints to create a specific experienced reality, much like an electron appearing in a defined position in space upon measurement.

This perspective also suggests that the present (and our soon to be experienced past) was selected by the confluence of multiple events and processes that occurred across many levels in relevant individual, group, and organization systems. For instance, the interaction of a specific social unit (e.g., individuals), a particular context (i.e., setting), and a particular technology (i.e., form of interaction) could be understood as working simultaneously *together* to guide the way people construct the present through their actions. In this way alternative pasts could have easily happened had any of these elements been different.

To account for these observations, our QATC perspective proposes that the future flows toward the present and eventual past as a wave of interacting potentialities—most of which are not directly experienced and are only realized through careful retrospection, such as *counterfactual thinking*. Counterfactual thinking involves reconsidering the past and examining how situational factors or one's behavior could have been different, leading to different outcomes. For example, missing an airplane by five minutes might lead one to mentally examine the many possible ways one could have arrived at the gate five minutes earlier and, ideally, to build some of these ways into one's routine to avoid missing a future flight. Thus, a crucial issue for individuals, groups, organizations, and societies is to use processes like counterfactual thinking to understand how a present is selected from many different potential alternatives that once existed in the future, rather than how the past leads to one future state. Like driving through a city with many streets, there are infinitely many routes and destinations, but we only experience the route taken. Alternative potentialities could be illustrated by a good road map, which would enable the driver to retrospectively consider the other routes that could have been taken. However, there is no map for navigating organizational futures since the metaphorical roads that carry organizational processes forward have not yet been constructed by human actions. A QATC addresses this issue by adopting a process-oriented perspective that attempts to understand how different presents are actively created. This perspective can, therefore, help unleash creativity and optimism for understanding how potentialities are realized by highlighting the role of proactive change and emphasizing that many potentialities are always available, which is less evident when we adopt an entity-guided view of the past.

Creating the Present from Multiple Futures

The creation of novel futures from a QATC can be illustrated by a historical example. The development of microprocessors at Intel in the early 1970s occurred as a response to serendipitous events, not as a planned product development. Microprocessors emerged from a creative and elegant engineering solution to a customer's request at Intel in 1969 to produce a different type of memory chip. This new design created an emergent bottom-up strategy that interacted with other events so that in less than a decade Intel changed from a memory chip producer to a microprocessor powerhouse, and it led Intel to exit the memory chip market in 1985 (Hazy, 2008). Microprocessors, in turn, allowed the development of PCs, laptops, smartphones, the internet, and social media so that people, markets, and social institutions could be closely connected all over the globe. Although this chain of developments seems like a logical progression when viewed retrospectively, most people would not have foreseen these changes in the 1970s, and they reveal only some of the many potentialities that were available in the coming future. From a QATC perspective, the challenge for both organizational leaders and organizational science is to recognize that these potentialities exist and to understand how alternative potentialities can be created.

A crucial issue in understanding change is how and why some potentialities develop as the future approaches the present, whereas others fail to emerge. As explained in the following section, we maintain that the selection of one possible alternative occurs as constraints in hierarchically organized systems attenuate some potentialities while enhancing others. These constraints interact with each other and with inputs from organizational processes to create *attractors* (i.e., points of stability created by reinforcing systems that channel processes in definite and consistent ways) for interpretation and behavior. However, we believe that these spaces are hard to find because (1) they tend to emerge between multiple layers of hierarchically nested systems as superpotentiality states collapse to create new realities; (2) they are created by factors that organize processes and, thus, are one step removed from events and behaviors; and (3) looking backward leads to a description of behaviors and events in entity terms, a tendency that is exaggerated by language that better suits entity than process explanations (Hernes & Maitlis, 2010).

Returning to the previous Intel example can illustrate these three points. First, the collapse of spaces to create new realities such as microprocessors reflected a process involving sets of available resources (e.g., knowledge, financial resources, and human capital) found at the conjunction of specific customers and engineering groups at Intel, and, later on, it involved the entire organization and the market systems surrounding Intel. Thus, the creation process involved actions at boundaries of multiple systems. Over time, these resources interacted in unforeseeable ways to produce new products and resources that eventually created a new identity for Intel. Further, although the historical progression of Intel's development could be described easily as a sequence of events, it is more difficult to describe the underlying processes that were involved in creating these dynamic changes. This is because a description of processes required the development of new explanatory principles and the use of an abstract system to model their flow and interaction (Hazy, 2008). Hence, consistent with our second point, process descriptions were one step removed from events and behaviors. Third, language naturally focuses on the description of stable entities (nouns), rather than describing the processes (verbs) used to create these entities (Hernes & Maitlis, 2010; Purser & Petranker, 2005). This is problematic because processes evolve continuously and may be understandable only once they have become defined and are available for retrospection. In other words, the underlying processes and outcomes of organizational change may remain unclear at any point existing prior to the present as the future moves forward to continually shape the present.

There is also an important sociological factor associated with looking backward that makes future potentialities harder to see. As Eaton, Visser, Krosnick, and Anad (2009) document, control over others and institutions tends to peak in one's mid-forties, but futures are often created by younger individuals. Thus, looking backward emphasizes the skills and preferences of a generation that will have less influence in the future. For example, Schmidt (2014) notes that leadership in virtual teams is different than it is in face-to-face teams, but he also emphasizes that younger individuals, who are more familiar with virtual relations via experiences with Facebook, Google Hangouts, or Twitter, are more adept at virtual teams. He predicts that as these individuals become more numerous in the workforce, how work is done will change, new potentialities will be created, and the nature of virtual leadership processes will change.

Because it emphasizes potentialities in the future, a QATC perspective implies that radical nonlinear change should be a common, unavoidable occurrence, as illustrated by our previous descriptions of sociological (Schmidt, 2014) and technology-related (Hazy, 2008) change. However, we maintain that organizational and institutional systems also resist change, which helps explain why many potentialities are never pursued. In effect, organizational systems may ebb and flow stochastically around changing set points (attractors), as described by the notion of dynamic homeostasis in open systems theory (Katz & Kahn, 1978). In the following section we provide a more detailed examination of how organizational system dynamics and stability are both created and maintained within a QATC framework by paying attention to the nature of constraints using a multilevel theory perspective. We also address how processes can combine serendipitously and interactively to realize some of the alternative potentialities that the future can offer.

QATC AND DYNAMIC ORGANIZATIONAL SYSTEMS

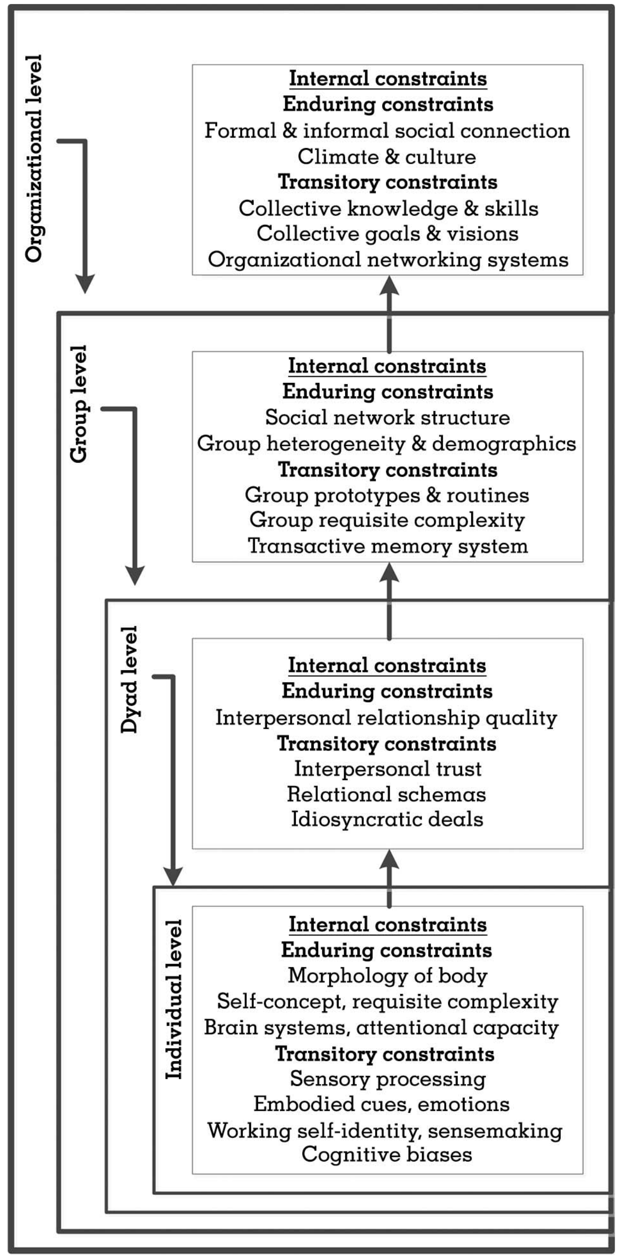
A general limitation of many organizational theories is that they examine processes at one level independently from the next level and at only one time period, rather than explaining how multilevel organizational phenomena dynamically unfold over time. However, social systems exist as a conglomerate of many smaller subsystems that function semi-autonomously within a grander scale (Contractor, Wasserman, & Faust, 2006; Simon, 1981; Sytch & Tatarynowicz, 2014; Weick, 1976). A QATC can be applied at any of these levels, which will change the calibration of time from milliseconds at lower levels to months or years at higher levels. But it is between and at the junctures of these different systems that the processes fostering or retarding the development of new potentialities are most critical. This is because it is at these connections and junctures that the emerging outputs of processes at one level are transformed into an input that is meaningful at another level.

To demonstrate, it is well known that complexity in systems depends on their hierarchical nature (Aime, Humphrey, DeRue, & Paul, 2014; Kozlowski & Klein, 2000; Simon, 1981), where the linkages between system levels are often represented as constraints (Dinh, Lord, & Hoffman, 2014; Freeman & Ambady, 2011; Read et al., 2010). Some constraints are momentary, such as emotions, goals, or cognitions. They are implemented by fast processes, and they may dissipate rapidly from an environment after being created. Other more enduring constraints, such as knowledge, relational ties, and even the morphology of one's body, can influence the emergence of events over longer periods of time. Consequently, the evolution of psychological and organizational phenomena can occur over different levels and time periods, involving processes that require milliseconds, minutes, days, weeks, and/or years to be completed.

Whether these phenomena are best conceptualized as ongoing processes or consequences of stable entities also depends on the durability of key constraints and the level at which theory is focused. Because higher-level systems generally change more slowly than lower-level systems, higher-level constraints generally channel emergent lower-level processes in one direction or another, thereby allowing some potentialities to develop while others never materialize. However, lower-level systems must aggregate their outputs over multiple cycles to align with the slower cycling rhythm of higher-level systems, and this aggregation can sometimes move the entire system to new states. For example, individual selective attention processes can be constrained by higher-level mental schemata, such as goals or social perception categories, but higher-level mental schemata can also be changed by the interaction of bottom-up processing systems like motivations and emotions. Such dynamics affect one's assessment of potentialiaties because, as Johnson-Laird (1983) maintained, we know reality from the mental models we construct.

Figure 3 provides an illustration of the types of hard and soft constraints that organizational researchers postulate operate at individual, dyadic, group, and organizational levels. Additional levels of analysis (e.g., societal, environmental) could also be considered, but here we focus on these four to provide a simpler basis for theorizing. The influence of top-down multilevel processes is demonstrated in research that shows how such internal constraints as the ethical culture created at the company level for U.S. soldiers in Iraq cascaded downward to create an external constraint that affected the ethical culture at the platoon and then the squad level (Schaubroeck et al., 2012). Similarly, internal constraints created by dynamic processing systems related to cognition, embodiment, and emotions can collectively mold the interpretation of encountered stimuli, creating meaning that is aggregated across time or people to produce higher-level outcomes, such as interpersonal cognitions, feelings of trust, or group resources (Dinh et al., 2014; Lord, Hannah, & Jennings, 2011; Smith-Jentsch, Kraiger, Cannon-Bowers, & Salas, 2009; Sy, Côté, & Saavedra, 2005). In a general sense, some constraints may be subject to explicit description, such as identity or social norms (Schultz & Hernes, 2013), while others operate automatically, such as how an active mental schema affects access to related information (Bargh, Chen, & Burrows, 1996). Also, as one moves downward in this figure, processes operate on faster time scales.

FIGURE 3
Internal and External Transitory and Enduring Constraints Operating at Individual, Dyad, Group, and Organizational Levels of Analysis



It is important to note the role of the connections in Figure 3, which provides a medium for cross-level integrative processes. These connections can be manifested as the physical technologies (e.g., internet, social media), materials (e.g., infrastructure, transportation), and network characteristics (e.g., network structure, density) that affect how organizational systems and organizational members interact. They also refer to less tangible connections that exist intrapersonally and interpersonally, such as an individual's mental structure and his or her interpersonal relational networks. These connections not only permit the transmission and diffusion of information but also provide a mechanism allowing recursive feedback loops to modify the structural characteristics and the functioning of participating units and individuals within the network (Dourish & Mazmanian, 2013). Although we have drawn these connections as being hierarchical and seemingly stable to maintain parsimony in Figure 3, it is important to note that each connection may have multiple end points that can change over time as new and old connections are created or dissolved.

Our application of quantum theory maintains that it is the operation of external constraints from higher-level systems and internal (horizontal) constraints from systems at the same level, along with the connections among these levels, that constrain encountered potentialities to create attractors and, if these constraints are sufficient, to cause potentialities to collapse as the future moves toward the present. For example, an encounter with coworkers around the coffee machine may have no potential to activate mental schema with respect to leadership, so leadership may be in an inactive state. However, in a different context, such as an organizational meeting to address an impending crisis, there is the potential for leadership to emerge as access to an individual's leadership (or followership) self-views influences the granting or claiming of leadership for oneself or others (DeRue & Ashford, 2010). In this latter situation the aggregated effects of contextual constraints, individual constraints, and horizontal constraints from other actors can affect whether the interpretation of an individual's actions will coalesce around a common social meaning, such as being perceived as a leader. This is just one of many ways that constraints identified in Figure 3 could affect the translation of future potentialities into an experienced reality.

When interpreted using a QATC, this figure suggests that the actualization of constraints reflects the *entanglement* (i.e., interdependencies among entities and context) of a state and context such that emergent events that have no analogue in the past can form—a principle referred to as the *principle of noncompositionality* (described further in the Appendix). This principle suggests that novel outcomes can emerge when future potentialities collapse to create a singular event at a particular level. However, radical change isn't expected to be continually created because attractors channel processes in a consistent way since past information is loosely maintained within attractors. Thus, attractors can gradually evolve over time as new phenomena are experienced, and they can also serve to organize actions or guide the reconstruction of past memories (Hernes, 2014; McClelland, McNaughton, & O'Reilly, 1995).

The influence of attractors is shown in several notable examples. For instance, goal orientations, which function as emergent attractors formed from a "massively interconnected" set of higher- and lower-level goal constructs (DeShon & Gillespie, 2005), channel thoughts and actions in terms of goal relevance (Johnson, Chang, & Lord, 2006). Similarly, enduring organizational processes have been described by Lok and De Rond (2013), who show how highly institutionalized processes were maintained over long periods of time because deviations were contained through maintenance work by organizational members. It is important to note, however, that the recursive dynamics among multilevel processes can cause the potentialities of local and global states to collapse in unforeseen ways, which shifts the positioning of attractors. In this way the contoured surface of probability waves as seen in Figure 2 continually changes over time, thereby affecting the potentialities available to an organization.

In short, Figure 3 illustrates how events at any chosen level are a function of the internal constraints within that level and the external constraints from higher- or lower-level contexts. Further, each juncture of systems is a nexus for understanding how the future flows into the present. When these multilevel considerations are combined with a QATC perspective, the resulting framework provides insight for understanding how internal and external constraints acting at multiple levels set limits on the way processes emerge at a particular level. In general, weak constraints foster gradual, incremental change, whereas strong constraints promote stability and periodic discontinuous change. This framework also addresses how lower-level outputs cumulate to affect higher-levels systems in a way that is sensitive to quantum theory's understanding of the flow of time.

TIME, PROBABILITY WAVES, AND ORGANIZATIONAL UNCERTAINTY

It is easiest to grasp the nature of time-related change by looking at snapshots of different probability waves organized across time rather than a continually changing probability wave. Such a representation is provided in Figure 4, which shows probabilities at each time in terms of attractor regions (hills) that are defined by sets of internal and external constraints. This figure shows five time slices from a local or global system, where time is also a dimension. It suggests that as time moves forward from the distant future toward the present, some constraints become solidified as different contexts are experienced, which causes the surface of the probability wave to evolve continuously, becoming more definite based on the presence of specific contexts and the constraints in these contexts. Thus, one could think of Figure 4 as reflecting hypothetical time slices showing what the probability wave would look like if it were measured at a particular time.[3] This change is reflected in terms of fewer but higher hills as one moves from the left to the right of this figure and as potentialities become restricted to more likely states. *What Figure 4 represents, then, is a guide for theorizing about the future and how it can become the present as constraints change*. In terms of clock time, Figure 4 could involve months or years if our focus was on change at an organizational level, but it could reflect only a few seconds if our focus was on the emergence of individual-level mental constructs or emotions.

Considered in the context of Figure 4, a QATC highlights several critical issues for social science. From an ontological perspective, understanding how the present came about may require insight into how it may have materialized from many different alternative possibilities, a process that is difficult to achieve, as we previously described. In addition, Figure 4 represents this uncertainty in a way that is not as clear without the tools of quantum theory, which suggest a transition from a superpotentiality state to a definite state and a reconceptualization of the flow of time as a future that moves into the present (F $\rightarrow$ P). Also, the representation in Figure 4 is tied to the notion that phenomena in dynamic systems emerge subject to internal and external constraints, and this conceptualization helps us understand how actions and events in the present can project at least some distance into the future (P $\rightarrow$ F) through their effects on process constraints.

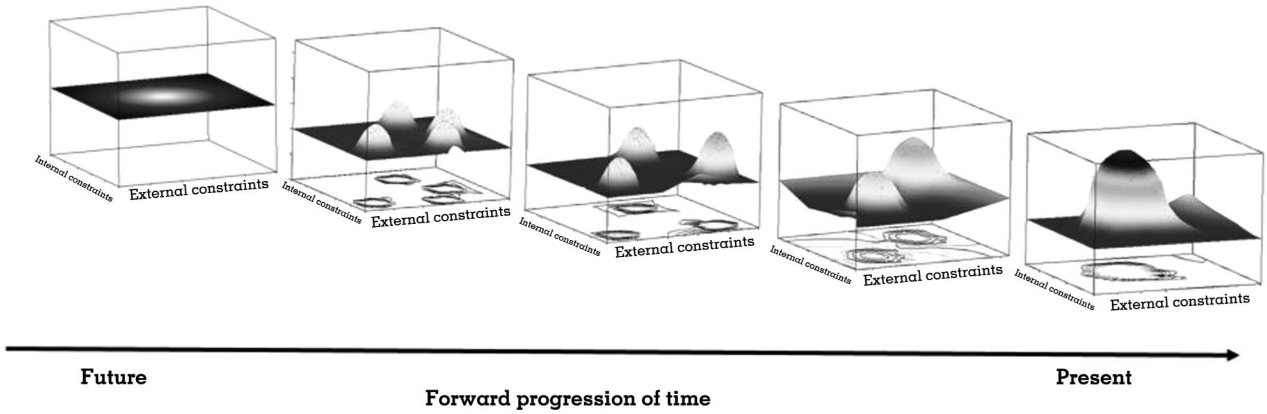
In other words, stability comes not from enduring attributes but from the way that those attributes act upon constraints, thereby channeling emerging processes. Habit, for example, is not an entity but, rather, a pattern of behavior that reoccurs in a certain context because the processes generating behavior operate similarly in that context (Barsalou, Niedenthal, Barbey, & Ruppert, 2003; MacDonald, 2008). Change, then, depends on altering those channeling processes. For example, chronic eating habits can be disrupted by factors as simple as eating with a nondominant hand, because they shift the underlying process generating behavior from an automatic to a more conscious process (Neal, Wood, Wu, & Kurlander, 2011).

IMPLICATIONS FOR THEORY, RESEARCH METHODS, AND PRACTICE

On a general level, a QATC framework and feed-forward models (FFMs) both share an appreciation for understanding process, which is evident in qualitative-based research (e.g., MacKay & Chia, 2013; Plowman et al., 2007). However, as a conceptual framework, a QATC framework provides a counterpoint to the typical FFMs of organizational change and individ-

[3] One advantage of a quantum theory perspective is that probability waves can evolve over time while still in an indefinite state (Busemeyer & Bruza, 2012), whereas models of evolution based on classical probability theory (e.g., Markov models) explain evolution in terms of moving from one definite state to another. Thus, quantum theory better enables the continuous interactions among various constraints as the future approaches the present to change potentialities that have never been realized.

FIGURE 4
Changes in Probability Waves Through Time Beginning in an Indeterminate Superpotentiality State to a Definite State As the Probability Wave Is Acted Upon by Internal and External Constraints



ual development because it emphasizes the influence of unrealized potentialities, which may be useful in guiding theory generation. Exhibit 1 provides a comparison of these two models, highlighting the many differences between the two perspectives. In the following sections we use Exhibit 1 as a structure for understanding the theoretical and methodological implications of a QATC framework compared to traditional FFMs.

Theoretical Implications of a QATC Framework

Direction of time and the nature of concepts. A QATC framework offers several new grounding assumptions for organizational research. First, it is useful to conceptualize the future as flowing into the present, which can be represented by the evolution of probability wave functions as various types of constraints are encountered and interact. As does Hernes (2014), a QATC perspective emphasizes the temporality of processes. By reversing the arrow of time, it implies that the present is continually created by the conjoining of various constructs where the nature of concepts—including attitudes, emotions, beliefs, and group and organizational structures—all reflect the translation of a superpotentiality state into a defined state at a particular time and context.

One advantage of beginning with an undefined future for understanding how systems change is that we do not start with the assumption that organizational processes are predictable or consistent. Instead, beginning with an undefined future recognizes the significance of uncertainty and the existence of future alternative potentialities. This difference can be seen easily by comparing the first and last panels of Figure 4. Here the flow of time from a future to a present acknowledges that constraints themselves may be dynamic, shaping concepts such as meaning and mental categories "on-the-fly" (Barsalou, 1983). Thus, quantum theory's emphasis on context and evolving processes can be particularly helpful, especially when a process like sensemaking is understood as an enacted, ongoing endeavor where the meaning attached to the environment is discovered by and dependent on a person's iterative interactions with his or her environments (Gabora et al., 2008; Gibson, 1986; Hernes & Maitlis, 2010; Weick, 1995).

Further, a transition from an undefined future to an experienced present naturally emphasizes the process of creation by individuals and collectives, whereas a past and present to future perspective starts with unit attributes (e.g., organizational climate or culture) and examines their effects on processes. Process views and their emphasis on patterns and dynamics are, therefore, more fitting as a theoretical framework for understanding change than is a focus on enduring attributes of individuals or systems (Hernes, 2014; Langley et al., 2013). This is not to say that focusing on the enduring attributes of individual and organizational entities should be abandoned, particularly when they exhibit very little variation as ascertained from longitudinal

EXHIBIT 1
Theoretical, Methodological, and Practical Implications of a QATC and FFM

Theoretical Implications

1. Direction of time and the nature of concepts
   A QATC conceptualizes the future as flowing into the present into the past (i.e., F → P → P), whereas an FFM perspective conceptualizes the past as leading to the present to the future (i.e., P → P → F).
2. Representation of event probabilities
   A QATC is process focused and recognizes the potentialities available to interacting organizational units, whereas an FFM perspective emphasizes stable entities and thereby limits potentialities that are considered.
3. Relation among micro and macro multilevel systems
   A QATC suggests that the interconnections among multilevel systems are critical to the dynamics of organizational phenomena. These interconnections also challenge efforts to achieve organizational ambidexterity. An FFM perspective more often attends to local processes occurring independently in one or another level.

Methodological Implications

1. Alternative possibilities
   A QATC implies that methodological approaches based on FFM perspectives that include meta-analyses and those dependent on a single sampling distribution are limited in predicting future behaviors or adding insight on dynamic individual, group, and organizational processes.
2. Quantum probability theories
   A QATC recognizes that new probability axioms and mathematical formalisms may be needed to better represent the creative combination of constructs through noncompositional processes involving the entanglement of states and contexts.
3. Dynamics of organizational processes
   A QATC stresses the continual involvement of multilevel interactive processes originating from individual, group, and organizational levels of analysis in influencing organizational phenomena. Quantitative methodologies including quantum probability theories and computational modeling are available, consistent with QATC.
4. Emergence of concepts
   A QATC emphasizes that organizational and cognitive concepts may exist in a superpotentiality state that is influenced by measurement procedures. An FFM perspective suggests that organizational and cognitive concepts exist in a predefined state not likely to change with measurement procedures.

Practical Implications

1. Decision making and forecasting biases
   A QATC suggests that techniques such as prospection and counterfactual thinking, when they enable rather than limit the consideration of alternative potentialities, can offset or prevent decision-making biases created by feed-forward tendencies when the past is generalized to predict the future.
2. Creation of new futures
   A QATC offers insights on the creation of new futures as multiple potentialities are explored and the innovations they uncover diffuse through social systems. In contrast, an FFM would represent futures as branching from the present, thereby suggesting fewer potentialities.
3. Conflict between intuitive beliefs and abstract representations
   Competition between a QATC and FFM perspective may result in conflicting strategies for organizational problems. Since each influences the efficiency of decision making, individual differences in the dependency of intuitive versus abstract thinking should be considered.

studies (Dinh et al., 2014). However, the recognition that unforeseeable processes can create new entities, as well as remain stable over time, is an advantage of a QATC framework. Thus, a QATC framework can direct attention to emergent phenomena like creativity, social capital, and the factors that can catalyze these phenomena, such as leadership (Uhl-Bien & Marion, 2009), variability in emotional experience (Bledow, Rosing, & Frese, 2013), and heterogeneity among unit members (Page, 2007). Understanding and managing these processes, to the extent that managing emergent processes is possible, is a critical strategic issue for organizational leadership. In contrast, an FFM emphasizes entities that describe the past and are expected to endure into the future.

Although beyond the scope of this article, one technique, provided by Scharmer and Kaufer (2013), facilitates understanding and influencing processes. Consistent with our perspective, these scholars argue that one needs to focus on leading from an emerging future to successfully address many contemporary problems. Their framework also emphasizes developing one's listening capacities to foster a more encompassing self; increasing collaborative, idea-broadening efforts; and employing radically different economic and social logics instead of just perpetuating the ways of thinking that generated pressing problems.

Representation of event probabilities. Second, a focus on the past naturally emphasizes the continuity of entities that are, in turn, used to describe and explain past and future events. For example, one might explain an individual's past behavior in terms of underlying personality traits, which are then used to predict future behavior. The five-factor model of personality and the use of personality measurement scales to predict behavior would characterize such an approach. This entity view of personality leads to a point estimate for behavior consistent with the individual's pattern of personality traits and a probability distribution around that estimate. A QATC, in contrast, recognizes the many potentialities that may occur in the future, leading an individual to behave quite differently. Thus, there are multiple points and multiple probability distributions around those points, as can be seen in a probability wave distribution.

Because events or behaviors emerge from the interaction of context and an entity (or, as we have proposed, higher-level contextual constraints operating on processes that emerge at a lower hierarchical level), how this combination affects the probability of a specific outcome is a critical concern. Here quantum theories can represent probabilities in ways that traditional probability theories cannot, thereby offering better insight for understanding how processes operate and unfold. For example, a QATC perspective can represent how the interaction among entities can create entirely new entities or events, which is not easily addressed by FFM perspectives.

Relation among micro and macro systems. Although we recognize that scenario-based forecasting (MacKay & McKiernan, 2004) and ambidextrous leadership (O'Reilly & Tushman, 2013; Rosing, Frese, & Bausch, 2011) have some of the elements that are described by a QATC, our perspective goes beyond these approaches by suggesting that individuals are nested within much larger systems, which constrain processes, eliminate potentialities, and cause select outcomes to emerge. We have argued that it is at the nexus of these nested systems that the present is created from the dynamic interplay of higher- and lower-level systems across many different temporal cycles. Thus, multilevel modeling approaches are critical for understanding how entities and processes are continually created, but the nature of relevant constructs and the span of time in which things happen change with the level of analysis. This perspective differs from those offered by FFM that promote the modeling of isolated, independent systems.

Within organizational settings, a QATC can be applied to improving organizational innovation and ambidexterity. As this research shows, firms have difficulty managing both exploration and exploitation (March, 1991; O'Reilly & Tushman, 2013) since different organizational units have different needs and goals at different times, making intersystem synchronization difficult (Davison, Hollenbeck, Barnes, Sleesman, & Ilgen, 2012; Zaccaro, Marks, & DeChurch, 2012). Our framework adds two insights to this issue. First, because many future potentialities may exist in an indefinite state until they are conjoined with a context, they cannot be known until they are tried out. Thus, exploration is a fundamental part of creating entirely new and different futures. Second, creating some futures may require the enactment of sets of constraints different from those being used in the present. A challenge in initiating change, therefore, is to recognize that using techniques that solidify extant constraints at one or another level to exploit present strategies may make it more difficult for organizations to explore alternatives and innovate. For example, vertical integration that allows increased control of an organization's resources may also reduce its capacity to explore alternative strategies through actions such as outsourcing or adopting new technologies (Aime et al., 2014).

Leaders can encourage exploration when they encourage others to do things differently, to experiment, to think independently, and to deviate from normal routines (Rosing et al., 2011). Such actions reduce current constraints, which facilitates the discovery of new potentialities. In contrast, Rosing et al. note that exploitation involves closing actions by leaders that reduce variability and solidify constraints by activities such as developing guidelines and monitoring activities. In brief, a QATC framework suggests that interventions that aim to increase (versus restrict) organizational innovation should consider how configurations (versus independent variables) of microlevel to macrolevel processes and entities can interact over time to catalyze or obstruct the attainment of desired organizational outcomes.

Methodological Implications of a QATC Perspective

Alternative possibilities. First, changing the direction of time and using probability waves to represent time-related processes highlight the fact that the present represents just one potential state. Thus, the present or the past is more predictable than the future, and expectations based on the past may not generalize to a future that can be quite different. This idea has profound methodological implications since most methodology in organizational science is retrospectively oriented. For example, meta-analysis focuses on integrating past research based on the notion of point estimates and a single sampling distribution. Although meta-analytical techniques can provide a general overview of the past relationship among constructs, the statistical technique's approach toward aggregating across many different contexts interferes with its ability to consider the effects of context and time on the evolution of organizational phenomena.

Because of these limitations, we believe that meta-analytical approaches and those based on a single sampling distribution would have limited value in predicting future behaviors or in explaining the moment-to-moment variability observed in individual-level (Dinh & Lord, 2012; Fleeson, 2001; Read et al., 2010), group-level (Crawford & LePine, 2013; Smith-Jentsch et al., 2009), and organizational-level (Feldman & Pentland, 2003; MacKay & Chia, 2013) phenomena, unless there were sufficient constraints to create stability in organizational and individual processes. In addition, models that are overly fit to the certain past may not accurately generalize to the future, which has many potentialities and may be characterized by entities that are in different states. When the future changes dramatically from the past, less restrictive models may have better predictive validities. For example, the decision-making and forecasting literature shows that unit-weighted combinations of inputs equal or outperform multiple regression-based combinations in cross-validation studies (Bobko, Roth, & Buster, 2007). Such results are often explained in terms of sampling error creating shrinkage for multiple regression-based predictions. Our interpretation, though, is that it is not sampling error so much as the fact that phenomena change, making models built on the past somewhat outdated when applied in the future.

A related issue involves the inability to include emergent phenomena and constructs in models because they did not exist in the past. This problem may necessitate the use of computational modeling methodologies, rather than static retrospective questionnaires (Kozlowski et al., 2013). These methodological techniques have become increasingly available to scholars and include agent-based modeling (e.g., Dionne & Dionne, 2008), nonlinear stochastic modeling (e.g., Guastello, 2001), genetic algorithms (e.g., Fernandez, Cotta, & Ceballos, 2008), and neural computational modeling (e.g., Eliasmith, 2013; for an overview of the uses and applications of computational modeling, see Kozlowski et al., 2013, and Vancouver & Weinhardt, 2012).

Traditional quantitative approaches, which focus on quantifying individual and organizational constructs, are also valuable, particularly when complemented with qualitative naturalistic methods (e.g., observation, interviews, experience sampling) that offer scholars an understanding of *how* and *why* certain constructs vary in different contexts or circumstances. In this way the capacity to provide a descriptive and detailed catalogue of organizational phenomena can complement quantitative approaches by triangulating findings and providing a broader description of these phenomena (Pope & Mays, 1995). Although such methods can excel at describing complexity in organizations and the contextual factors that created the experienced reality, focusing on what has happened and how events occurred may overemphasize the certainty in the past, and it may underemphasize the alternative realities that may have been likely in the past, as well as the new potentialities that are offered by the future.

Quantum probability theories. Second, quantum theorists would argue that under uncertainty the evolution of physical and psychological phenomena more closely obeys the mathematical formalisms of quantum theories (i.e., von Neumann axioms, which are defined in terms of events projected onto spatial representations, as shown in the Appendix), rather than classical probability theories (i.e., Kolmogorov axioms, which are defined on sets) that are foundational to the statistical models used in psychological research (Busemeyer et al., 2011; Wang, Busemeyer, Atmanspacher, & Pothos, 2013). Because the mathematical axioms that guide quantum probability theories can account for the interactive influence of simultaneously occurring contexts and states (Busemeyer & Bruza, 2012; Hughes, 1989; Wang et al., 2013), applications of quantum probability theories to the organizational sciences may not only allow scholars to better model the organizational context but also help overcome the limitations associated with employing artificial paradigms that subtract uncertainty from realistic phenomena in psychological research (Pothos & Busemeyer, 2013).

Dynamics of organizational processes. Third, we proposed that the multilevel dynamics inherent in the evolution of organizational phenomena require a process view that examines how individual and group behaviors are affected by both external constraints from higher-level systems like groups and organizations and lower-level internal constraints from cognitions, embodiment, and affect. By focusing on how processes unfold over time at the nexus of systems, a QATC framework provides both quantitative and qualitative analytical approaches that can be applied at multiple levels and across multiple time frames. Although beyond the scope of this article, quantum probability theories and quantum mechanics have been used to understand how alternative possibilities can be created or destroyed by different interacting contexts, actors, and events over varying expanses of time. These possibilities may be revealed best through the use of newer information processing architectures that rely on vector-based representations (see Busemeyer & Bruza, 2012, and Eliasmith, 2013). Similar to neural network modeling and symbolic architectures, such systems can learn rules as they create solutions, mimicking the type of creative processes that, we argue, occur in natural systems.

Emergence of concepts. Fourth, a profound implication of a QATC approach is that, for much of the time, many aspects of organizational phenomena may exist in a form that is unknown to observers because these constructs are in a superpotentiality state. Like a computer monitor that is turned off, features are not activated when a concept, attitude, emotion, trait, group climate, or organizational process is divorced from context. Not only are features or properties revealed solely through specific measurement procedures, which can create contextual effects of their own (Busemeyer & Bruza, 2012; Hughes, 1989), but these individual or organizational properties may not exist outside of a physical context or the mental framework used by perceivers to create meaning (Hernes & Maitlis, 2010; Langley & Tsoukas, 2010; Weick, 2010). They may also change as contexts change, reflecting state-like, rather than trait-like, properties.

This perspective seems most appropriate for phenomena like emotions, which align with alternative states of an individual (Barsalou et al., 2003), but it has broader application than one might realize, applying to traits and constructs such as leadership and trust, which may manifest only in certain situations. Indeed, some constructs may be better assessed from a process perspective since they are continually evolving (DeShon & Gillespie, 2005; Gabora et al., 2008; Hernes, 2014; Hernes & Maitlis, 2010), rather than from a perspective that views constructs as stable entities that can be assessed with retrospective measures. This is particularly true when the conjoining of a context and construct creates new features. Here the quantum representation of concepts allows the states of concepts to change continually as new contexts are encountered (Gabora & Aerts, 2002).

These possibilities are rarely considered, in part because we assume that most constructs in social and organizational science are stable entities (Feldman & Lynch, 1988). This view may reflect the exaggerated stability created by an orientation toward the past, whereas a view of the future collapsing to create the present emphasizes many potentialities and directs attention to the processes that allow some of these potentialities to emerge while others remain unrealized. It also raises such questions as how alternative futures could be imagined, created, or redirected in ways that change emerging experiences. As eloquently stated by Weick, managerial work may be akin to a poetic process—"the imaginative process of creating forms out of 'airy nothing'" (2010: 102). The challenge for organizational science is to capture this creative process, which we maintain could be facilitated using the formalisms provided by quantum theory.

Implications for Practice

Decision-making and forecasting biases. A QATC perspective maintains that there are always multiple paths to the future, and some are associated with pasts that did not occur but may better characterize future situations than the past that did occur. This suggests that failing to consider alternative possibilities may lead to severe decision-making fallacies. For example, research has shown that *hindsight* (Arkes, Faust, Gulimette, & Hart, 1988) and *foresight biases* (MacKay & McKiernan, 2004), which involve using past experiences to predict the future, are the cause of many organizational failures and executive decision-making errors because they interfere with the ability to successfully anticipate or plan for alternative future events (e.g., Arrfelt et al., 2013; Brown & Eisenhardt, 1999; Dane & George, 2014). This sense of certainty promotes efforts that exploit only one future possibility, when there are many equally probable possibilities. These types of biases are evident when corporate decision makers make seemingly well-placed investments to "ensure" the future survival of their organization. As Arrfelt et al. (2013) demonstrate, however, these plans may interfere with the firm's ability to grow and innovate, especially when investments fail to produce intended benefits while also consuming valuable resources. When reinforced over time, prior interpretations may become "locked in" to create a rigid action pattern, labeled *path dependence,* that constrains the ability to craft adaptive solutions and strategies (Sydow, Schreyögg, & Koch, 2009).

However, decision-making biases can be avoided when organizational decision makers are able to recognize that alternative outcomes are possible when planning for future events. This may involve the use of *forecasting* or prospection to simulate possible events that can happen in the future. As Seligman et al. (2013) argue, there is a natural proclivity for humans to mentally travel into the future, and this is enabled as individuals combine (and recombine) memories of their past experiences to simulate the likely occurrence of both familiar and novel experiences. Prospection and the broadening of cognitive perspective can also occur with the cycling of negative and positive affect over time (Bledow et al., 2013; George & Zhou, 2007), or when members are engaged in cohesive collaborative teams, since these interpersonal work configurations enable members to flexibly entertain multiple perspectives and work strategies. The leveraging of interpersonal relationships to acquire new perspectives and potentialities can be especially advantageous because there are many types of precarious situations that confront organizational decision makers—each requiring its own unique solution (Milliken, 1987; Wiltbank, Dew, Read, & Sarasvathy, 2006). Group complexity, which is dynamically constructed (Hannah, Lord, & Pearce, 2011; Page, 2007), may help reveal these potentialities. The effectiveness of prospection can be limited, however, when mental simulations of the future omit essential features, such as when they rely on general heuristics, are based on nonrepresentative past information like relying on a single salient memory, or are decontextualized by not accounting for environments (Gilbert & Wilson, 2007).

Creating new futures. A QATC perspective can help one see that the future is more malleable than one typically realizes. Taleb (2010) describes "black swans" as unexpected, impactful events that change the course of history, and he explains that they are only understandable retrospectively, when new mental schemata become widely accepted because of black swan events. Our QATC perspective offers a different view, a view that helps explain how black swan events can occur when one doesn't accept the past as given but, instead, considers alternative potentialities and their implications for the future. As this process generalizes across individuals, which it does when individuals are part of socially connected networks, reality can eventually shift in dramatic ways, producing discontinuous rather than incremental change.

Conflict between intuitive beliefs and abstract representations. Although there is evidence to suggest that forecasting the future based on the past can yield effective strategizing when the recent past is generalized to an anticipated proximal future (Arrfelt et al., 2013; Gavetti & Levinthal, 2000), organizational decision makers are often pressed to formulate distal or long-term interventions and strategies to satisfy requirements that are different from those experienced in the present. In these instances a QATC perspective may be especially valuable since it is an abstract, unrestricted method for thinking about how the future will become the present.

However, conflicts may arise when the use of one perspective is favored over another, particularly when intuitive, experience-based perspectives are contrasted with more analytic approaches, as is often the case with views on climate change. In order to use a QATC perspective to guide decision making, therefore, one must be able to manage the greater complexity and uncertainty associated with this abstract framework. Although an area for future research, this approach may be more acceptable to individuals with a future rather than a past time orientation (Shipp, Edwards, & Lambert, 2009), individuals with greater intrapersonal complexity (Lord et al., 2011), or individuals who can tolerate greater risk and anxiety (Hirsh, Marr, & Peterson, 2012), such as those who are embedded within diverse, richly connected social-relational networks (Lee, Bachrach, & Lewis, 2014).

An Application to Leadership Emergence

Heretofore our discussion of a QATC framework has been abstract and general. In this section we emphasize a specific content domain—leadership—to illustrate how principles developed in quantum physics can be insightfully applied to organizational and societal issues.

A QATC approach to the problem of modeling leadership emergence. An individual is perceived to be a leader when his or her attributes and behaviors activate a leadership-defining cognitive structure or schema in perceivers. This cognitive structure has been shown to be recreated each time it is used, subject to a variety of constraints both external (e.g., leader attributes, context) and internal (e.g., momentary emotions, use of leadership versus follower schemas) to the perceiver (Hanges, Lord, & Dixon, 2000; Lord, Brown, Harvey, & Hall, 2001). Thus, the schema influencing leadership perception is itself dynamic and can be viewed as an attractor that organizes and amplifies stimulus interpretations (Hanges, Lord, Godfrey, & Raver, 2002). Consequently, different perceivers, or the same perceiver in different contexts, can define leadership differently.

To see how this process can create problems for scholars attempting to model such a dynamic phenomenon, it is useful to compare perceptions of males and females. The potential leader being evaluated can be a powerful constraint on the leadership schemas perceivers use to integrate behavioral input over time (Brown, Marchioro, Tan, & Lord, 1998; Rosette, Leonardelli, & Phillips, 2008; Sy et al., 2010). A critical question, then, is whether the probability of leadership emergence differs for males and females when they demonstrate the same pattern of behavior. To address this issue, we need a representational system that can include types of behavior (i.e., agentic, communal, passive) and different perceptual schemas for males and females, and that also permits operations that will estimate the relevant probabilities for emergent leaders.

The issue of jointly representing different categorical systems is "new and unique to quantum theory, and it is [sic] never been raised within classic theory" (Busemeyer & Bruza, 2012: 32). This issue can also be thought of as an issue of compatibility of the male- and female-oriented leadership schema, where the term *compatibility* has a special meaning. *When events and constructs share a common representational structure (or basis in quantum theory; Busemeyer & Bruza, 2012), they are deemed compatible, whereas incompatible events and constructs require a different representational structure (or basis) to be evaluated.* Bias in social perceptions such as leadership may then be associated with perceivers having different representational systems.

The uncertainty principle developed by Heisenberger in the field of quantum physics also can be applied to incompatible representation systems (Busemeyer & Bruza, 2012). Applying this principle suggests that when a male-oriented representational structure is used, male leaders can be evaluated with certainty, but the perceiver will be uncertain with respect to the probability that agentic, communal, or passive females will emerge as leaders; similarly, when a female-oriented representational system is used, the perceiver can evaluate female targets with certainty, but the probability that agentic, communal, or passive males will emerge as leaders will be uncertain. This schema incompatibility problem and its relation to uncertainty may help account for the well-documented difficulty females have in obtaining leadership roles in many of today's organizations. Specifically, the "glass ceiling" experienced by females may, in part, reflect the uncertainty that perceivers experience when evaluating a female's leadership potential using their dominant male-oriented leadership schema.

Using the principles and formalisms of quantum theory, we briefly show in Table 1 how the processing of leadership emergence can be represented, and in the following section we provide a detailed description of how these formalisms can be implemented. Readers not interested in this quantum formalism should focus on the concepts emphasized in the left and center columns of Table 1, whereas readers interested in a more precise representation may also want to reexamine Table 1 after reading the Appendix.

Detailed application of quantum theory to leadership emergence. In developing a representational model of leadership emergence, we begin by using an *N*-dimensional vector space (also known as a Hilbert space) that represents a superpotentiality state. The vectors encompassing this state, labeled *basis vectors*, correspond to specific events, such as a male (or female) exhibiting a specific type of behavior emerging as a leader. For example, the emergence of a male leader exhibiting agentic, passive, or communal behavioral patterns can be represented as the orthogonal vectors *AX, AU*, and *AV*, whereas the emergence of a female leader exhibiting similar behavioral patterns can be represented by a different set of orthogonal vectors, *BX, BU*, and *BV*. In addition, a normalized *state vector*, S, which represents a general *state of leadership,* is also contained within the larger *N*-dimensional space, and this state vector can be projected onto each basis vector to indirectly determine the probability that a male (or a female) leader exhibiting a specific behavioral pattern will emerge as a leader. This projection, then, represents the collapse of a superpotentiality state as it is conjoined with a specific context. For example, when *S* is projected onto *AU*, this collapse yields an amplitude that reflects the probability an agentic male leader will emerge.[4] Quantitatively speaking, the coordinates of these vectors can be obtained from observed data using various questionnaire and experimental research methodologies (e.g., Wang, et al., 2013).

We have described the effects of one external constraint, the gender of a target person, on the perceptual structure (which is analogous to sets of basis vectors) used to understand leadership emergence. This same approach can be extended to reflect how other types of external constraints could change the way leaders emerge. For example, Lord, Foti, and De Vader (1984) showed that context (i.e., military, business, education, etc.) changed the nature of leadership prototypes used to define categories. More recently, Sy et al. (2010) demonstrated that the ethnicity of a target has the same effect, and Rosette et al. (2008) showed that the race of a leader changes leadership prototypes. These different perceptual bases could *all* be represented in an abstract *N*-dimensional vector space in a manner analogous to the representation of gender. Internal constraints may also be included in this geometric space, such as the effects of a perceiver's current emotions or goal states. In short, what this application of a QATC shows is how a wide variety of multilevel constraints can be represented in a geometric space. Operations in this space can then model the way a potential leader's behaviors are interpreted in a group context to create an emerging reality.

Finally, we should stress that although this application emphasizes the social-cognitive literature on leadership perceptions, our framework is more general and could be applied to

[4] In this example the male and female spaces are incompatible because no common subspace can represent analogous events for male and female targets. Further, it can be shown (see Busemeyer & Bruza, 2012: 40–41) that the points corresponding to the emergence of an agentic, communal, or passive male leader, which involve a single vector in the male space, require a combination of all three vectors in the female space. Thus, when there is certainty with respect to the male behavioral vector space, since each vector represents a different collapse of the superpotentiality state, there is uncertainty in using the behavioral space to evaluate females because all three basic vectors are involved. Similarly, using the female behavioral space, the point corresponding to the probability that an agentic, communal, or passive male will emerge involves a combination of all three vectors in the male behavioral space. Hence, when certainty exists for a female, uncertainty exists for the male.

TABLE 1
Quantum Formalism of Leadership Emergence for Men and Women Exhibiting Agentic, Passive, and Communal Leadership Type Behaviors

Organizational Entity	Quantum Terminology	Quantum Formulization
Representation of organizational entities and phenomena		
A state in which an individual has not yet been designated as a leader	General state of leadership or a superpotentiality state	Represented as a state vector *S* that is contained within *N*-dimensional space; this initial general state is assumed to have a unit length equal to 1
A male or a female target exhibiting an agentic, passive, or communal behavioral pattern	Basis vector	A one-dimensional basis vector *AX*, *AU*, or *AV* representing the emergence of a male exhibiting a specific behavioral pattern, or *BX*, *BU*, or *BV* representing the emergence of a female exhibiting an analogous behavioral pattern
Representation of the processing of leadership		
Accessing a male-oriented leadership schemas interferes with the ability to access a female-oriented leadership schemas	Incompatibility of male and female leader schemas	The basis vectors representing male and female involve different coordinate systems within the *N*-dimensional space
A male and a female experience a context providing an opportunity for leadership where a specific individual emerges as a leader	Collapse of a superpotentiality state, creating probabilities for a specific type of individual to emerge as a leader	The general state vector *S* is projected onto each vector corresponding to male or female behavioral patterns, *AX*, *AU*, *AV* or *BX*, *BU*, *BV*
Representation of leadership outcome		
Perceiver's leadership schemas for males and females are highly dissimilar	Alternative schemas are incompatible	The amplitude of projections onto analogous basis vectors is not equal for males and females
Perceiver's leadership schemas for males and females are highly similar	Alternative schemas are compatible	The amplitude of projections onto analogous basis vectors is equal for males and females

many issues or hierarchical levels. Broadly, extending these ideas to a QATC framework suggests that *new perspectives cannot be evaluated with certainty using perceptual schema grounded in the past; they can only be evaluated with certainty after one has shifted to a new perceptual system*. This principle may help explain why people and organizations have so much difficulty assessing new potentialities that exist in the future.

LIMITATIONS

No theory is without limitations, and despite the numerous theoretical and methodological benefits that a QATC perspective affords, there are several limitations and areas that merit future consideration. First, research on quantum mechanics and quantum probability theory have only recently been applied to understanding social and psychological phenomena, such as decision making (Busemeyer & Bruza, 2012; Wang et al., 2013), consciousness (Hameroff & Penrose, 2014), and cognitive constructivism (Gabora et al., 2008). In addition, only a handful of scholars have begun to apply quantum formalism and its mathematical representations to understanding individual and organizational phenomena (e.g., Eliasmith, 2013). Although it may be many years until a meaningful integration of quantum theory with organizational research is realized, we maintain that a QATC perspective can advance and enrich organizational research in many ways, and we encourage its entanglement with the organizational sciences.

Second, we applied our QATC perspective to understand organizational phenomena, rather than psychological phenomena as they relate to time travel. As our reviewers pointed out, numerous scholars and philosophers over the last century have debated how human beings have understood the concept of time (Mead, 1932; Sherover, 2003; Suddaby, Foster, & Trank, 2010; Weick, 1995), which may also vary across diverse cultural perspectives. Although our perspective borrows the concept of mentally reversing the arrow of time to consider a future that collapses into the present to understand the present and the past (Sherover, 2003), our application addressed the probabilistic nature of uncertainty in real-life phenomena, rather than the philosophical question of the meaning of time and its relevance to human existentialism. However, the application of quantum theory to the development and resolution of our subjective knowledge of time may yield interesting findings and may be pursued in future endeavors.

Last, we also acknowledge that for most individuals there is a substantial learning curve in understanding vector-based mathematics in quantum theory. The upside, though, is that we have come a long way in terms of developing a mathematical or energy-based understanding of changes, which can serve as helpful guidelines for organizational science.

CONCLUSION

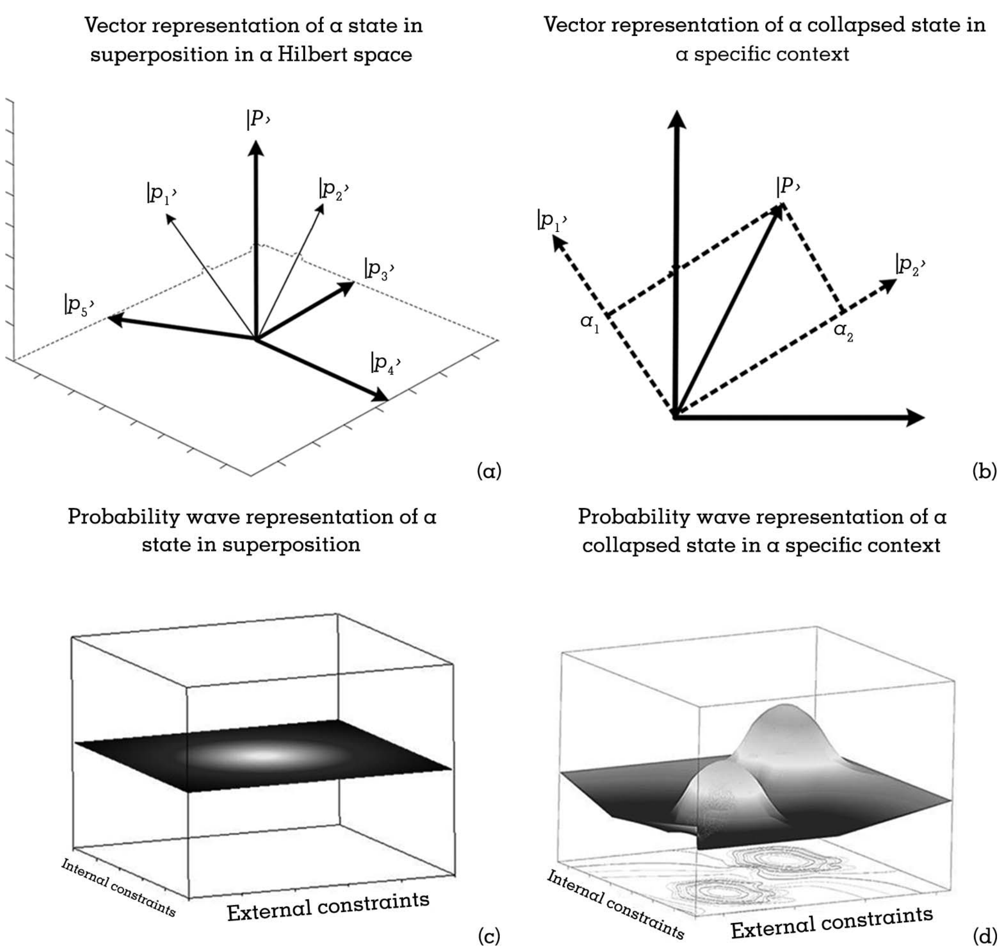
We proposed a quantum approach to conceptualizing travel through time as a metastructure for addressing process-related issues associated with both stability and change. By reversing the arrow of time and thinking of the future as flowing into the present, we can conceptualize the present as being created from a superpotentiality state as it is conjoined with a particular context to create an entangled present. This approach also illustrates that the future holds multiple potentialities that may each define the present. We believe that this QATC approach provides a useful framework that can help advance organizational theory and research by offering a novel perspective challenging many long-standing assumptions on certainty, time, and processes of realizing change for individuals, groups, and organizations. Further, it suggests that there is greater flexibility in how the future will unfold than many people realize, in part because they have difficulty evaluating future potentialities using perspectives grounded in the past. Finally, as our leadership example showed, QATC also offers new avenues for theoretical development, and it raises profound quantitative and methodological questions.

APPENDIX: REPRESENTATION OF QUANTUM PROCESSES

Vectors and Hilbert spaces. In quantum theory a physical or psychological entity is represented as a *system* within a multidimensional, mathematical structure known as a *Hilbert space*. In this space *vectors* (lines created by a point connected to an origin with a pointed arrow) form *subspaces* (a plane spanned by vectors), which define the collection of elementary outcomes that can be generated by a system. Vector spaces allow for rich representations of phenomena within a high dimensional space, and they can represent the compositional qualities of natural language, as well as the meaning of more complex compositions that conjoin constructs with unique contexts (Eliasmith, 2013: 297–299).

A graphic representation of a Hilbert space that contains a few sample vectors is shown in Figure 5a. In this figure there are two general types of vectors, which are represented by the combined symbols |X>, called a "ket." Mathematically, *basis vectors* (e.g., $|p_1>$, $|p_2>$, $|p_3>$, . . . $|p_n>$) represent the alternate elemental events and outcomes that can be obtained by a system representing a physical entity or a psychological state. Also, a *state vector* (|P>) is a general state of a system (e.g., one's mental or emotional state), which is normalized to have a length of 1. When projected onto basis vectors, it yields an amplitude that, when squared, is the probability

FIGURE 5
Hilbert Space and Probability Wave Representations of a Superpotentiality State and a Collapsed State



Note: (a) A Hilbert space containing a sample set of orthogonal basis vectors ($|p_1\rangle$, $|p_2\rangle$, . . . $|p_5\rangle$) and a state vector ($|P\rangle$) in a superpotentiality state. The linear aggregation of sets of basis vectors, which represent the alternative possibilities of a holistic state of a physical or psychological phenomenon that may be at an individual, dyadic, group, and organizational level, forms the Hilbert space. (b) A cross-sectional view of the Hilbert space when a state vector, $|P\rangle$, is projected onto its basis vectors as it becomes entangled with a specific context. The probability of $|p_1\rangle$ occurring is higher than $|p_2\rangle$ since the squared amplitude of $|p_1\rangle$ is greater than the squared amplitude of $|p_2\rangle$. (c) A probability wave representation of a state vector, $|P\rangle$, in a superpotentiality state. (d) A collapsed Hilbert space when state vector, $|P\rangle$, becomes entangled with a specific context.

of occurrence for the specific event represented by the basis vector. To illustrate, a set of basis vectors can refer to the possible range of specific, observable outcomes (e.g., specific felt emotions like happy and sad) that can be derived from a more descriptive, nondetermined state (e.g., emotionality). Using these mathematical notations, as shown in Figure 5b, the probability that a particular elemental event or outcome will occur is determined by the projection amplitude (perpendicular distance) of the state vector ($|P>$) onto each elemental event contained within the subspace ($|p_1>$, $|p_2>$,. . . $|p_n>$). These probabilities are often based on empirical data, or they may result from mathematical operations in Hilbert spaces. When a specific outcome does occur, it reflects a change in the state of the system, where the indefinite state (i.e., emotionality, $|P>$), *collapses* onto a definite state (e.g., happy, $|p_1>$), which, in turn, acquires specific features and qualities that can be measured and observed.

When a collapse occurs, probabilities become more certain. This process is shown in Figure 5b using a vector representation, and in Figure 5d as a *probability wave*, in which a contoured surface is drawn over the projection amplitudes extending from a state vector onto the many basis vectors composing a subspace. These figures show that compared to a system in a superpotentiality state (Figures 5a and c), collapsing systems have more definite outcomes as certain events have higher projection amplitudes, which are represented as peaks in the probability wave in Figure 5d. In contrast, Figure 5c shows that the probability a state vector will collapse onto a particular event is equally likely across all events (i.e., the amplitudes are equal in the flat surface), and, therefore, retains high potentiality.

In this illustration we provided a rudimentary example of how a single state (i.e., emotionality) has the potential to be actualized in many different ways as it becomes conjoined with a specific context. However, multiple states (emotions, values, attitudes, mental schemas) and/or physical entities (e.g., people) can be simultaneously experienced by larger systems, such as groups and organizations. Notably, these elements of organizational systems could also be represented in a Hilbert space, given quantum theory's ability to represent interacting subspaces (referred to as *tensor products*). Concretely, complex interactive processes could be represented when our example is extended to include multiple interacting Hilbert spaces that each represent different individual, group, and organizational states and entities. When multiple, interacting Hilbert spaces are considered together, systems of constraints can convolve simultaneously to affect the global state of a system (as an individual, group, organization) as it travels through time. The mathematics behind computing tensor products for interacting subspaces is beyond the scope of this article (see Hughes, 1989).

Noncompositionality and the nexus of hierarchical levels. In terms of semantic spaces, noncompositionality occurs when the combination of two concepts produces a qualitatively different concept. To say that an automobile is a lemon implies attributes not possessed by most cars or most lemons, and it also drops some features of each (Hampton, 2013), in that we are not implying that the car is yellow or reliable. Compositional combination, in contrast, simply includes all the attributes of both concepts, as in "black cat." The issue of how to conceptualize and represent noncompositional concepts and their underlying semantic space is complex and has a rich history (see Busemeyer & Bruza, 2012: Chapters 5–7). It is of importance to a QATC because we argue that the future collapses into the present at the nexus of hierarchical levels, and this process involves the construction of meaning, either mentally or through organizing actions, by combining external and internal constraints.

How meaning is created at the nexus of systems is a particularly challenging area for understanding combinations, because a common meaning system is often absent as one crosses hierarchical levels and time frames. For example, one's self-identity creates a rich internal framework for reacting emotionally, interpreting events, and translating this interpretation into actions. However, when we cross the boundary to a social system such as a dyadic relation, even though each member has a self-system, the collective social system does not have the same semantic space as each individual. Understanding the relational meaning of the combined identity, then, is a compositionality issue, which can explain dyadic (or group) identities. It is important to understanding issues such as the creation of complexity in organizations because complexity is in part created from the interaction of dissimilar individuals (Page, 2007) as it produces novel outcomes.

The advantage of thinking of compositionality issues in terms of a quantum framework is that it can go beyond intersective semantics (e.g., black cats) and use multidimensional Hilbert spaces to represent concepts. For example, each individual's self-relevant meaning for an event, such as the change in state of a system, could be represented by different basis vectors in a Hilbert space. These different basis vectors, in turn, might yield different probabilities for a specific emotional reaction. What is critical in this representation is that in predicting each person's emotional or behavioral reaction, the other individual can be viewed as a context or a given, as in Bayesian mathematics, but the combinations can be represented more richly in terms of tensor products (see Busemeyer & Bruza, 2012: 156). Returning to our hierarchical system example, it is therefore possible to represent the set of external constraints at the nexus of systems as a context that interacts with the internal constraints at a lower level in producing an outcome.

REFERENCES

Aime, F., Humphrey, S., DeRue, D. S., & Paul, J. B. 2014. The riddle of heterarchy: Power transitions in cross-functional teams. ***Academy of Management Journal,*** 57: 327–352.

Alvesson, M., & Sandberg, J. 2011. Generating research questions through problematization. ***Academy of Management Review,*** 36: 247–271.

Ancona, D. G., Goodman, P. S., Lawrence, B. S., & Tushman, M. L. 2001. Time: A new research lens. ***Academy of Management Review,*** 26: 645–663.

Arkes, H. R., Faust, D., Gulimette, T. J., & Hart, K. 1988. Eliminating the hindsight bias. ***Journal of Applied Psychology,*** 73: 305–307.

Arrfelt, M., Wiseman, R. M., & Hult, G. T. M. 2013. Looking backward instead of aspiration-driven influences on the capital allocation process. ***Academy of Management Journal,*** 56: 1081–1103.

Bakken, T., & Hernes, T. 2006. Organizing is both a verb and a noun: Weick meets Whitehead. ***Organization Studies,*** 27: 1599–1616.

Bargh, J. A., Chen, M., & Burrows, L. 1996. Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. ***Journal of Personality and Social Psychology,*** 71: 230–244.

Barsalou, L. W. 1983. Ad hoc categories. ***Memory & Cognition,*** 11: 211–227.

Barsalou, L. W., Niedenthal, P. M., Barbey, A., & Ruppert, J. 2003. Social embodiment. ***Psychology of Learning and Motivation,*** 43: 43–92.

Bledow, R., Rosing, K., & Frese, M. 2013. A dynamic perspective on affect and creativity. ***Academy of Management Journal,*** 56: 432–450.

Bluedorn, A. C., & Jaussi, K. S. 2008. Leaders, followers, and time. ***Leadership Quarterly,*** 19: 654–668.

Bobko, P., Roth, P. L., & Buster, M. A. 2007. The usefulness of unit weights in creating composite scores: A literature review, application to content validity, and meta-analysis. ***Organizational Research Methods,*** 10: 689–709.

Boroditsky, L., & Ramscar, M. 2002. The roles of body and mind in abstract thought. ***Psychological Science,*** 13: 185–189.

Brown, D., Marchioro, C., Tan, J. A., & Lord, R. G. 1998. ***Individual difference variables and leadership perceptions: Linear or catastrophic relationship?*** Poster paper presented at the annual meeting of the Society for Industrial and Organizational Psychology, Dallas.

Brown, S. L., & Eisenhardt, K. M. 1999. The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations. ***Administrative Science Quarterly,*** 42: 1–34.

Buckner, R. L., & Carroll, D. C. 2007. Self-projection and the brain. ***Trends in Cognitive Sciences,*** 11: 49–57.

Busemeyer, J. R., & Bruza, P. D. 2012. ***Quantum models of cognition and decision.*** Cambridge: Cambridge University Press.

Busemeyer, J. R., Pothos, E. M., Franco, R., & Trueblood, J. S. 2011. A quantum theoretical explanation for probability judgment errors. ***Psychological Review,*** 118: 193–218.

Contractor, N. S., Wasserman, S., & Faust, K. 2006. Testing multitheoretical, multilevel hypotheses about organizational networks: An analytic framework and empirical example. ***Academy of Management Review,*** 31: 681–703.

Crawford, E. R., & LePine, J. A. 2013. A configural theory of team processes: Accounting for the structure of taskwork and teamwork. ***Academy of Management Review,*** 38: 32–48.

Dane, E., & George, J. M. 2014. Unpacking affective forecasting and its ties to project work in organizations. ***Academy of Management Review,*** 39: 181–201.

Davison, R. B., Hollenbeck, J. R., Barnes, C. M., Sleesman, D. J., & Ilgen, D. R. 2012. Coordinated action in multiteam systems. ***Journal of Applied Psychology,*** 97: 808–824.

DeRue, D. S., & Ashford, S. J. 2010. Who will lead and who will follow? A social process of leadership identity construction in organizations. ***Academy of Management Review,*** 35: 627–647.

DeShon, R. P., & Gillespie, J. Z. 2005. A motivated action theory account of goal orientation. ***Journal of Applied Psychology,*** 90: 1096–1127.

Dinh, J. E., & Lord, R. G. 2012. Implications of dispositional and process views of traits for individual difference research in leadership. ***Leadership Quarterly,*** 23: 651–669.

Dinh, J. E., Lord, R. G., & Hoffman, E. 2014. Leadership perception and information processing: Influences of symbolic, connectionist, emotion, and embodied architectures. In D. V. Day (Ed.), ***The Oxford handbook of leadership and organizations:*** 29–65. New York: Oxford University Press.

Dionne, S. D., & Dionne, P. J. 2008. Levels-based leadership and hierarchical group discussion optimization: A simulation. ***Leadership Quarterly,*** 19: 212–234.

Dionysiou, D. D., & Tsoukas, H. 2013. Understanding the (re)creation of routines from within: A symbolic interactionist perspective. ***Academy of Management Review,*** 38: 181–205.

Dourish, P., & Mazmanian, M. 2013. Media as material: Information representations as material foundations for organizational practice. In P. R. Carlie, D. Nicolini, A. Langley, & H. Tsoukas (Eds.), ***How matter matters:*** 92–119. New York: Oxford University Press.

Eaton, A. A., Visser, P. S., Krosnick, J. A., & Anand, S. 2009. Social power and attitude strength over the life course. ***Personality and Social Psychology Bulletin,*** 35: 1646–1660.

Eliasmith, C. 2013. ***How to build a brain: A neural architecture for biological cognition.*** Oxford: Oxford University Press.

Epperson, M. 2004. ***Quantum mechanics and the philosophy of Alfred North Whitehead.*** New York: Fordham University.

Feldman, J. M., & Lynch, J. G. 1988. Self-generated validity and other effects of measurement on belief, attitude, intention, and behavior. ***Journal of Applied Psychology,*** 73: 421–433.

Feldman, M. S., & Pentland, B. T. 2003. Reconceptualizing organizational routines as a source of flexibility and change. ***Administrative Science Quarterly,*** 48: 94–118.

Fernandez, A. J., Cotta, C., & Ceballos, R. C. 2008. ***Generating emergent team strategies in football simulation videogames via genetic algorithms.*** Paper presented at the GAMEON'2008 conference, Valencia, Spain.

Feynman, R. P., Leighton, R. B., & Sands, M. 2010. (First published in 1965.) ***The Feynman lectures on physics. Volume III: Quantum mechanics.*** New York: Basic Books.

Fleeson, W. 2001. Toward a structure- and process-integrated view of personality: Traits as density distributions of states. ***Journal of Personality and Social Psychology,*** 80: 1011–1027.

Freeman, J. B., & Ambady, N. 2011. A dynamic interactive theory of person construal. ***Psychological Review,*** 118: 247–279.

Gabora, L., & Aerts, D. 2002. Contextualizing concepts using a mathematical generalization of the quantum formalism. ***Journal of Experimental and Theoretical Artificial Intelligence,*** 14: 327–358.

Gabora, L., Rosch, E., & Aerts, D. 2008. Toward an ecological theory of concepts. ***Ecological Psychology,*** 20: 84–116.

Gavetti, G., & Levinthal, D. 2000. Looking forward and looking backward: Cognitive and experiential search. ***Administrative Science Quarterly,*** 113: 113–137.

George, J. M., & Zhou, J. 2007. Dual tuning in a supportive context: Joint contributions of positive mood, negative mood, and supervisory behaviors to employee creativity. ***Academy of Management Journal,*** 50: 605–622.

Gibson, J. J. 1986. ***The ecological approach to visual perception.*** New York: Psychological Press.

Gilbert, D. T., & Wilson, T. D. 2007. Prospection: Experiencing the future. ***Science,*** 317: 1351–1354.

Greene, B. 2004. ***The fabric of the cosmos: Space, time, and the texture of reality.*** New York: Vintage Books.

Greene, B. 2011. ***The hidden reality: Parallel universes and the deep laws of the cosmos.*** New York: Vintage Books.

Guastello, S. J. 2001. Nonlinear dynamics in psychology. ***Discrete Dynamics in Nature and Society,*** 6: 11–29.

Hameroff, S., & Penrose, R. 2014. Consciousness in the universe: A review of the "Orch OR" theory. ***Physics of Life Reviews,*** 11: 39–78.

Hampton, J. A. 2014. Conceptual combination: Extension and intension. Commentary on Aerts, Gabora, and Sozzo. ***Topics in Cognitive Science,*** 6: 53–57.

Hanges, P. J., Lord, R. G., & Dickson, M. W. 2000. An information processing perspective on leadership and culture. A case for connectionist architecture. ***Applied Psychology: An International Review,*** 49: 133–161.

Hanges, P. J., Lord, R. G., Godfrey, E. G., & Raver, J. L. 2002. Modeling nonlinear relationships: Neural networks and catastrophe analysis. In S. Rogelberg (Ed.), ***Handbook of research methods in industrial/organizational psychology:*** 431–455. Oxford: Blackwell.

Hannah, S. L., Lord, R. G., & Pearce, C. L. 2011. Leadership and collective requisite complexity. ***Organizational Psychology Review,*** 1: 215–238.

Harrison, D. A., & McLaughlin, M. E. 1996. Structural properties and psychometric qualities or organizational self-reports: Field tests of connections predicted by cognitive theory. ***Journal of Management,*** 22: 313–338.

Hazy, J. K. 2008. Leadership or luck? The system dynamics of Intel's shift to microprocessors in the 1970s and 1980s. In M. Uhl-Bien & R. Marion (Eds), ***Complexity and leadership. Part I: Conceptual foundations:*** 379–415. Charlotte, NC: Information Age.

Helzer, E. G., & Dunning, D. 2012. Why and when peer prediction is superior to self-prediction: The weight given to future aspiration versus past achievement. ***Journal of Personality and Social Psychology,*** 103: 38–53.

Hernes, T. 2014. ***A process theory of organizations.*** Oxford: Oxford University Press.

Hernes, T., & Maitlis, S. 2010. Process, sensemaking, and organizing: An introduction. In T. Hernes & S. Maitlis (Eds.), ***Process, sensemaking, & organizing:*** 27–37. Oxford: Oxford University Press.

Hirsh, J. B., Mar, R. A., & Peterson, J. B. 2012. Psychological entropy: A framework for understanding uncertainty-related anxiety. ***Psychological Review,*** 119: 304–320.

Hoffman, E. L., & Lord, R. G. 2013. A taxonomy of event-level dimensions: Implications for understanding leadership processes, behavior, and performance. ***Leadership Quarterly,*** 24: 558–571.

Hughes, I. G. 1989. ***The structure and interpretation of quantum mechanics.*** Cambridge, MA: Harvard University Press.

Ibarra, H., & Barbulescu, R. 2010. Identity as narrative: Prevalence, effectiveness, and consequences of narrative identity work in macro work role transitions. ***Academy of Management Review,*** 35: 135–154.

Johnson, R. E., Chang, C. H., & Lord, R. G. 2006. Moving from cognition to behavior: What the research says. ***Psychological Bulletin,*** 132: 381–415.

Johnson-Laird, P. N. 1983. ***Mental models: Towards a cognitive science of language, inference, and consciousness.*** Cambridge, MA: Harvard University Press.

Kaplan, S., & Orlikowski, W. J. 2013. Temporal work in strategy making. ***Organization Science,*** 24: 965–995.

Katz, D., & Kahn, R. L. 1978. ***The social psychology of organizations.*** New York: Wiley.

Klarner, P., & Raisch, S. 2013. Move to the beat—Rhythm of change and firm performance. ***Academy of Management Journal,*** 56: 160–184.

Koehler, D. J., White, R. J., & John, L. K. 2012. Good intentions, optimistic self-predictions, and missed opportunities. ***Social Psychology and Personality Science,*** 2: 90–96.

Kozlowski, S. W. J., Chao, G. T., Grand, J. A., Braun, M. T., & Kuljanin, G. 2013. Advancing multilevel research design: Capturing the dynamics of emergence. ***Organizational Research Methods,*** 16: 581–615.

Kozlowski, S. W. J., & Klein, K. J. 2000. A multilevel approach to theory and research in organizations: Contextual, temporal, and emergent processes. In K. J. Klein & S. W. J. Kozlowski (Eds.), ***Multilevel theory, research, and methods in organizations: Foundations, extensions, and new directions:*** 3–90. San Francisco: Jossey-Bass.

Langley, A., Smallman, C., Tsoukas, H., & Van de Ven, A. H. 2013. Process studies of change in organization and management: Unveiling temporality, activity, and flow. ***Academy of Management Journal,*** 56: 1–13.

Langley, A., & Tsoukas, H. 2010. Introducing, "perspectives on process organization studies." In T. Hernes & S. Maitlis (Eds.), ***Process, sensemaking, & organizing:*** 1–26. Oxford: Oxford University Press.

Lee, J. Y., Bachrach, D. G., & Lewis, K. 2014. Social network ties, transactive memory, and performance in groups. ***Organization Science,*** 25: 1–17.

Lok, J., & De Rond, M. 2013. On the plasticity of institutions: Containing and restoring practice breakdowns at the Cambridge University Boat Club. ***Academy of Management Journal,*** 56: 188–207.

Lord, R. G., Brown, D. J., Harvey, J. L., & Hall, R. J. 2001. Contextual constraints on prototype generation and their multi-level consequences for leadership perceptions. ***Leadership Quarterly,*** 12: 311–338.

Lord, R. G., Foti, R. J., & De Vader, C. 1984. A test of leadership categorization theory: Internal structure, information processing, and leadership perceptions. ***Organizational Behavior and Human Performance,*** 34: 343–378.

Lord, R. G., Hannah, S. T., & Jennings, P. L. 2011. A framework for understanding leadership and individual requisite complexity. ***Organizational Psychology Review,*** 1: 104–127.

MacDonald, K. B. 2008. Effortful control, explicit processing, and regulation of human evolved predispositions. ***Psychological Review,*** 115: 1012–10311.

MacKay, R. B., & Chia, R. 2013. Choice, change, and unintended consequences in strategic change: A process understanding of the rise and fall of Northco automotive. ***Academy of Management Journal,*** 56: 208–230.

MacKay, R. B., & McKiernan, P. 2004. The role of hindsight in foresight: Refining strategic reasoning. ***Futures,*** 36: 161–179.

March, J. G. 1991. Exploration and exploitation in organizational learning. ***Organization Science,*** 2: 71–87.

McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. 1995. Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. ***Psychological Review,*** 102: 419–457.

Mead, G. H. 1932. ***The philosophy of the present.*** Chicago: Open Court Publishing.

Milliken, F. J. 1987. Three types of perceived uncertainty about the environment: State, effect, and response uncertainty. ***Academy of Management Review,*** 12: 33–143.

Neal, D. T., Wood, W., Wu, M., & Kurlander, D. 2011. The pull of the past: When do habits persist despite conflict with motives? ***Personality and Social Psychology Bulletin,*** 37: 1428–1437.

O'Reilly, C. A., & Tushman, M. L. 2013. Organizational ambidexterity: Past, present, and future. ***Academy of Management Perspectives,*** 27: 324–338.

Page, S. W. 2007. ***The difference: How the power of diversity creates better groups, firms, schools, and societies.*** Princeton, NJ: Princeton University Press.

Plowman, D. A., Baker, T. E., Kulkarni, M., Solansky, S. T., & Travis, D. V. 2007. Radical change accidentally: The emergence and amplification of small change. ***Academy of Management Journal,*** 80: 515–545.

Pope, C., & Mays, N. 1995. Qualitative research: Reaching the parts other methods cannot reach: An introduction to qualitative methods in health and health services research. ***bmj,*** 311: 42–45.

Pothos, E. M., & Busemeyer, J. R. 2013. Can quantum probability provide a new direction for cognitive modeling? ***Behavioral and Brain Sciences,*** 36: 255–327.

Purser, R. E., & Petranker, J. 2005. Unfreezing the future: Exploring the dynamics of time in organizational change. ***Journal of Applied Behavioral Science,*** 41: 182–203.

Rae, A. I. M. 2005. ***Quantum physics: A beginner's guide.*** Oxford: Oneworld.

Read, S. J., Monroe, B. M., Brownstein, A. L., Yang, Y., Chopra, G., & Miller, L. C. 2010. A neural network model of the structure and dynamics of human personality. ***Psychological Review,*** 117: 62–92.

Rosette, A. S., Leonardelli, G. J., & Phillips, K. W. 2008. The white standard: Racial bias in leader categorization. ***Journal of Applied Psychology,*** 93: 758–777.

Rosing, K., Frese, M., & Bausch, A. 2011. Explaining the heterogeneity of the leadership-innovation relationship: Ambidextrous leadership. ***Leadership Quarterly,*** 22: 956–975.

Scharmer, O., & Kaufer, K. 2013. ***Leading from the emerging future: From ego-system to eco-system economies.*** San Francisco: Berrett-Koehler.

Schaubroeck, J. M., Hannah, S. T., Avolio, B. J., Kozlowski, S. W. J., Lord, R. G., Trevino, L. K., Dimotakis, N., & Peng, A. C. 2012. Embedding ethical leadership within and across organizational levels. ***Academy of Management Journal,*** 55: 1053–1078.

Schmidt, G. B. 2014. Virtual leadership: An important leadership context. ***Industrial and Organizational Psychology: Perspectives on Science and Practice,*** 7: 182–187.

Schultz, M., & Hernes, T. 2013. A temporal perspective on organizational identity. ***Organization Science,*** 24: 1–21.

Seligman, M. E. P., Railton, P., Baumeister, R. F., & Sripada, C. 2013. Navigating into the future or driven by the past. ***Perpsectives on Psychological Science,*** 8: 119–141.

Sherover, C. M. 2003. ***Are we in time? And other essays on time and temporality.*** Evanston, IL: Northwestern University Press.

Shipp, A. J., Edwards, J. R., & Lambert, L. S. 2009. Conceptualization and measurement of temporal focus: The subjective experience of the past, present, and future. ***Organizational Behavior and Human Decision Processes,*** 110: 1–22.

Simon, H. E. 1981. ***The sciences of the artificial*** (2nd ed.). Cambridge, MA: MIT Press.

Smith-Jentsch, K. A., Kraiger, K., Cannon-Bowers, J. A., & Salas, E. 2009. Do familiar teammates request and accept more backup? Transactive memory in air traffic control. ***Human Factors,*** 51: 181–192.

Sonnentag, S. 2012. Time in organizational research: Catching up on a long neglected topic in order to improve theory. ***Organizational Psychology Review,*** 2: 361–368.

Suddaby, R., Foster, W. M., & Trank, C. Q. 2010. Rhetorical history as a source of competitive advantage. ***Advances in Strategic Management,*** 27: 147–173.

Suddendorf, T., & Corballis, M. C. 2007. The evolution of foresight: What is mental time travel, and is it unique to humans? ***Behavioral and Brain Sciences,*** 30: 299–351.

Sy, T., Côté, S., & Saavedra, R. 2005. The contagious leader: Impact of the leader's mood on the mood of group members, group affective tone, and group processes. ***Journal of Applied Psychology,*** 90: 295–305.

Sy, T., Shore, L. M., Strauss, J., Shore, T. H., Tram, S., Whiteley, P., & Ikeda-Muromachi, K. 2010. Leadership perceptions as a function of race-occupation fit: The case of Asian Americans. ***Journal of Applied Psychology,*** 95: 902–919.

Sydow, J., Schreyögg, G., & Koch, J. 2009. Organizational path dependence: Opening the black box. ***Academy of Management Review,*** 34: 689–709.

Sytch, M., & Tatarynowicz, A. 2014. Exploring the locus of invention: The dynamics of network communities and firms' invention productivity. ***Academy of Management Journal,*** 57: 249–279.

Taleb, N. N. 2010. ***The black swan.*** London: Penguin.

Uhl-Bien, M., & Marion, R. 2009. Complexity leadership in bureaucratic forms of organizing: A meso model. ***Leadership Quarterly,*** 20: 631–650.

Vancouver, J. B., & Weinhardt, J. M. 2012. Modeling the mind and the milieu: Computational modeling for micro-level organizational researchers. ***Organizational Research Methods,*** 15: 602–623.

Wang, Z., Busemeyer, J. R., Atmanspacher, H., & Pothos, E. M. 2013. The potential of using quantum theory to build models of cognition. ***Topics in Cognitive Science,*** 5: 672–688.

Weick, K. E. 1976. Educational organizations as loosely coupled systems. ***Administrative Science Quarterly,*** 21: 1–19.

Weick, K. E. 1995. ***Sensemaking in organizations.*** Thousand Oaks, CA: Sage.

Weick, K. E. 2010. The poetics of process: Theorizing the ineffable in organization studies. In T. Hernes & S. Maitlis (Eds.), ***Process, sensemaking, & organizing:*** 102–111. Oxford: Oxford University Press.

Whitehead, A. N. 1978. ***Process and reality.*** New York: Free Press.

Wiltbank, R., Dew, N., Read, S., & Sarasvathy, S. D. 2006. What to do next: The case for nonpredictive strategy. ***Strategic Management Journal,*** 27: 981–998.

Zaccaro, S. J., Marks, M. A., & DeChurch, L. A. 2012. Multiteam systems: An introduction. In S. J. Zaccaro, M. A. Marks, & L. A. DeChurch (Eds.), ***Multiteam systems: An organization form for dynamic and complex environments:*** 3–31. New York: Routledge.

Zerubavel, E. 2003. ***Time maps: Collective memory and the social shape of the past.*** Chicago: University of Chicago Press.

Robert G. Lord (robert.lord@durham.ac.uk) is a professor of leadership at Durham Business School, Durham University. He earned his Ph.D in organizational-social psychology at Carnegie Mellon University. His research focuses on leadership and social perceptions, organizational complexity, motivation, emotions, and information processing.

Jessica E. Dinh (jessica.dinh@durham.ac.uk) is a postdoctoral researcher at Durham Business School, Durham University. She earned her Ph.D. in industrial-organizational psychology from the University of Akron. Her research focuses on leadership, organizational complexity, and the sociocognitive processes that influence dynamic organizational behavior.

Ernest L. Hoffman (elh2@zips.uakron.edu) is a doctoral candidate studying industrial-organizational psychology at the University of Akron. He currently works as a management consultant for Personnel Research and Development Corporation (PRADCO). His research interests include leader identity, event-level performance management, and organizational emergence.