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Information Technology, Materiality, and Organizational Change: A Professional Odyssey

Daniel Robey
Georgia State University
drobey@gsu.edu

Chad Anderson
University of Nevada
chadanderson@unr.edu

Benoit Raymond
Université Laval
benoit.raymond@sio.ulaval.ca

Abstract

We begin with a retrospective reflection on the first author's research career, which in large part is devoted to research about the implications of information technology (IT) for organizational change. Although IT has long been associated with organizational change, our historical review of the treatment of technology in organization theory demonstrates how easily the material aspects of organizations can disappear into the backwaters of theory development. This is an unfortunate result since the material characteristics of IT initiatives distinguish them from other organizational change initiatives. Our aim is to restore materiality to studies of IT impact by tracing the reasons for its disappearance and by offering options in which IT's materiality plays a more central theoretical role. We adopt a socio-technical perspective that differs from a strict sociomaterial perspective insofar as we wish to preserve the ontological distinction between material artifacts and their social context of use. Our analysis proceeds using the concept of "affordance" as a relational concept consistent with the socio-technical perspective. We then propose extensions of organizational routines theory that incorporate material artifacts in the generative system known as routines. These contributions exemplify two of the many challenges inherent in adopting materiality as a new research focus in the study of IT's organizational impacts.

Keywords: *Information Technology, Organizational Change, Materiality, Affordances, Sociomateriality, Socio-Technical, Material Agency.*

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1. Preamble

In this paper, I (the first author) reflect on a career of intellectual problem solving and, along with my two co-authors (we), generate guidance for future research on information technology and organizational change. As my part in the odyssey of scientific exploration and discovery draws to a close, that odyssey continues through the efforts of a new generation of scholars, represented here by my co-authors, who were two of my last Ph.D. students. As such, I trace my personal research experiences as the foundation for future work, which has resulted in an unconventionally self-referential paper. We beg the reader's indulgence for departing from convention.

2. The Odyssey in Retrospect

A long history of studies exists to show the impacts of information technology (IT) on organizations, which supports the enduring assumption that technological innovation is associated with organizational change. We refer to this stream of research as "IT impact", even though this term unwarrantedly implies that organizational change is a direct consequence of IT. IT-impact studies use a variety of research methodologies to ascertain the effects of IT artifacts on dependent variables or outcomes of interest. For example, one of the earliest studies of IT impact applied longitudinal fieldwork to examine organizational changes associated with the implementation of mainframe computing in the 1950s (Mann & Williams, 1960). IT impact was identified early as one of the core topics in information systems research (Culnan, 1987), and it remains relevant today (Sidorova, Evangelopoulos, Valacich, & Ramakrishnan, 2008). Studying IT impacts continues because IT permeates an increasingly large scope of human activity. Organizations of all kinds across the globe are exposed to a seemingly endless progression of IT applications, which has fueled a keen interest in studying impacts at multiple levels of analysis. For example, Doherty, Champion, and Wang (2010) continue the long tradition of IT-impact research in their study of enterprise systems' impacts on the organizational structure of Chinese manufacturers.

The relationship between IT and organizational change can be thought of as an intellectual puzzle that has yet to yield a complete solution[1]. An intellectual puzzle arises when uncertainty remains regarding social phenomena; for example, how organizations develop and change (Mason, 2002). Researchers are attracted to such puzzles because they are difficult to solve and large enough in scope to sustain entire research programs. The intellectual puzzle examined in this paper may be stated succinctly as a broad yet simple research question: How is information technology implicated in organizational change? This framing suggests a general solution to the puzzle that is independent of specific technologies or organizations. Numerous scholars have actively engaged with this puzzle since the advent of commercial computing in the 1950s. For the first author, attempting to solve the intellectual puzzle of IT impacts has consumed over 40 years of sustained effort, and it is still not yet completed.

Our paper proceeds with a backward glance at my career of intellectual problem-solving, beginning with the application of contingency theory and continuing through several waves of theoretical development. The paper then shifts to the present, in which the contemporary theme of materiality is considered. After exploring the meaning of materiality and alternative ontological assumptions that underly research on the materiality of IT, we offer insights into the use of affordances in IT impact research. We then demonstrate how materiality may be integrated into organizational routines theory.

3. Contingency Theory

I (the first author) joined the discourse on IT impact in the early 1970s while I was a doctoral student. As a student in organization science, I was exposed to the theory *du jour* known as contingency theory, which arose in the 1950s and 1960s as organization theory changed from a largely prescriptive field into a theory-based discipline focused on explaining variation in organization

[1] Today, the term intellectual puzzle is often applied to games like Sudoku that are marketed as "apps" for short intervals of entertainment. Our use of the term, by contrast, is meant to refer to larger issues that may stimulate research and theory for decades.

structures. Contingency theory was part of an emerging recognition of organizations as open systems that interact with their environments. The proposal that organizations were like other types of living systems spawned the formulation of "general systems theory", which sought to explain structure and function across different levels of systems (e.g., individuals, groups, organizations, and societies) (von Bertalanffy, 1956; Miller, 1965; Kast & Rosenzweig, 1972). In common with other living systems, organizations would need to import resources from their environments and be designed in ways to ensure efficient and effective functioning (Katz & Kahn, 1978).

A branch of systems theory, known as "socio-technical systems" theory, declared organizations to be both social and technical (Emery & Trist, 1965), and the theory directed balanced attention to both social and technical factors. Early studies engaged directly with the material properties of work, such as the mechanization of extraction techniques in sub-surface coal mines (e.g., Trist & Bamforth, 1951). Socio-technical systems theory was later appropriated by the emerging field of information systems to formulate principles for designing information systems (Bostrom & Heinen, 1977; Mumford & Weir, 1979; Mumford & MacDonald, 1989). According to socio-technical design principles, system development should "jointly optimize" the social and technical subsystems of an organization. Socio-technical design ensured important attention to the social side of systems design (e.g., Bjørn-Andersen & Hedberg, 1977), which yielded insights into ways of overcoming user resistance to new systems and increasing fit between systems and organizations (Markus & Robey, 1983: Markus, 1984). However, the information systems field did not influence mainstream contingency theory, which took a different approach to theorizing the relationship between technology and organizational change.

In organization studies, contingency theory was exemplified by studies of organization structure that examined the "fit" between an organization and several contingency factors (e.g., Burns & Stalker, 1961; Emery & Trist, 1965; Lawrence & Lorsch, 1967). The most important contingencies at that time were organization size, environmental uncertainty, and technology (Robey & Sales, 1994). The basic argument was that organizations of different sizes, that operate in environments that varied in uncertainty, and that use different technologies were expected to exhibit structural characteristics that matched the contingencies in some way. Achieving a proper fit between contingencies and structure was hypothesized to be associated with greater organizational effectiveness.

The technology contingency in organization studies referred to "activities, equipment, and knowledge used to convert organizational inputs into desired outputs" (Johns, 1992, p. 8). This widely accepted definition dangerously combined social actions, material equipment, and abstract knowledge into a single theoretical concept. Such conglomerate concepts are symptoms of weak theorizing that, in retrospect, probably contributed to misunderstandings about the material aspects of technology. Ironically, researchers did not begin with unclear concepts of material properties of technology. To the contrary, they were the center of attention in one of the earliest contingency studies of technology (Woodward, 1965). Woodward identified material differences among three types of manufacturing processes: (1) unit and small batch production, (2) large-batch and mass production, and (3) continuous process production. These processes differed with respect to physical arrangements for transforming raw materials into finished products. By comparing the organizational structures of organizations in each technology category, Woodward offered early evidence of the relevance of technology to social organization. Each technology grouping adopted distinctive forms of organizing, which engendered consequences for organizational control, labor relations, and other outcomes. The most effective firms in each technology grouping adopted the grouping's modal organizational structure.

Woodward's approach to technology was limited to the study of manufacturing organizations. Organization science, of course, encompasses a wide range of organizations, including those rendering human services. Service organizations such as schools were also assumed to have technologies that allowed the inputs (clients) to be processed (served). To extend the concept of technology to include service organizations, Perrow (1967) redefined technology in terms of the variety and difficulty of problems encountered during the transformation of inputs into outputs. This new definition freed the concept of technology from its association with physical manufacturing and allowed its application to all organizations. Thus, the technology of a school was studied in terms of the variety of instructional and advisory programs in relation to the variety of student populations, not

in terms of the physical design of classrooms or instructional media. As a more abstract concept, technology becomes amenable to measurement with survey questionnaires, which thus enables scholars to accumulate larger samples without worrying about the physical properties of organizations. For example, the Aston studies produced numerous articles derived from survey measures of technology variables (e.g., Hickson, Pugh, & Pheysey, 1969; Pugh, Hickson, Hinings, & Turner, 1968). Given the interest in generating empirical articles, it is understandable that Perrow's (1967) approach became standard, with no objection to its exclusion of materiality.

My earliest work on IT impacts adopted a contingency approach. In addition to contingencies at the individual level (namely, work values and cognitive complexity) (Robey, 1974, 1976), I argued that the IT's impact on organization structure was contingent on the organization's environment (Robey, 1977). Thus, organizations operating in highly uncertain environments would apply IT to reinforce an appropriately decentralized structure, whereas organizations in highly certain environments would apply IT to reinforce a centralized structure. I supported this argument with my review of available early research, mostly case studies of new IT implementations (Robey, 1977). Unlike survey research on IT impacts (e.g., Klatzky, 1970; Whisler, 1970), these studies usually offer detailed descriptions of the IT applications being implemented and the business environments faced by the adopting organizations. My empirical research also took a case study approach that treated IT applications as material artifacts (Robey, 1981, 1983; Bjørn-Andersen, Eason, & Robey, 1986).

4. Challenges to Contingency Theory

Before long, the logic of contingency theory was challenged on several grounds[2]. One critique challenged contingency theory's assumption that outcomes can be explained with reference to a combination of known determinants. Contingency theory's central concern was explaining more of the variance in organizational structure by finding variables and including them in predictive models. Attewell and Rule (1984), for example, call for the inclusion of additional variables capable of explaining more of the variance in organizational impacts of IT:

> *We must identify those variables that can account for differential outcomes and examine them in a comparative study of a stratified sample of organizations. Variables include organizational size, industry type, degree of prior routinization or variability of work, degree of dependence upon a professional or high-skilled work force, and the patterns of information usage and information flow associated with the technologies in use* (p. 1189).

In this formulation, technology and other contingencies acquire the status of "determinants" of social outcomes. Although contingency theory represents a relatively soft form of determinism (Orlikowski, 2010), it nevertheless perpetuates the underlying assumption of technological determinism (Leonardi, 2013; Markus & Robey, 1988). This assumption can be challenged on both empirical and theoretical grounds.

Empirically, the accumulating studies of IT impact demonstrate that organizational consequences of IT are not as predictable as contingency theory would suggest (Robey & Boudreau, 1999). Indeed, contingency theory proved to be a weak predictor of empirical relationships in my own research, in which "the most commonly observed impacts were 'accidental' outcomes… resembling 'shotgun-bullet patterns'" (Bjørn-Andersen et al., 1986, p. 202). Although methodological improvements might help deterministic models become more predictive, many of the contradictions in empirical research cannot be resolved within the confines of deterministic theory (Robey & Boudreau, 1999). The misbehaved findings about IT impacts frustrate efforts to maintain what Poole and Van de Ven (1989) refer to as an "elusive consistency." To solve my intellectual puzzle, therefore, I felt that it was necessary to explain the complex social processes associated with IT implementation. My odyssey, therefore, turned toward developing and/or discovering alternative theoretical explanations of unanticipated and unintended IT impacts.

[2] Among these challenges, contingency theory's core concept of "fit" was subject to a plethora of interpretations ranging from statistical interaction effects to natural selection (Drazin & Van de Ven, 1985; Venkatraman, 1989; Weill & Olson, 1989). This issue continues to be addressed (Strong & Volkoff, 2010) but is beyond the scope of this article.

5. Process Theory

Although I engaged with numerous specific theories along the way, I was most attracted by the possibilities of process theories of organizational change (Markus & Robey, 1988; Newman & Robey, 1992). In contrast to the more prevalent variance theories, process theory avoids a deterministic logic in favor of explanations based on the dynamics of social processes (Mohr, 1982; Markus & Robey, 1988; Robey & Boudreau, 1999). For example, change might be associated with human intentions, but also with the collision between the intentions of parties with different agendas for change (Cule & Robey, 2004). Van de Ven and Poole (1995) articulate four distinct mechanisms accounting for the process of organizational change: teleological, dialectic, evolutionary, and life cycle mechanisms. In contrast to variance theory's search for a set of determinants and contingencies to explain variance in observed outcomes, process theory searches for explanations for how and why observed outcomes occur.

Without going into greater detail than necessary, my aim in this part of the odyssey was to write both conceptual and empirical papers that incorporated the insights derived from theories that interested me. In some cases, the empirical work never materialized, but, in most cases, I was able to work with co-authors with access to study sites where the theoretical ideas could be applied and extended using qualitative data. Table 1 lists the theories and the resulting publications. From this list, one might correctly conclude that I am promiscuous when it comes to theorizing. For me, theory is a practical tool to improve understanding rather than a sacred text demanding literal interpretation. Had I always been faithful to the scriptures of contingency theory, I would never have learned anything new, and hence my understanding of IT's implications for organizational change would have stagnated early. In my view, a professional odyssey requires continuous learning and discovery rather than repetition of what is already known.

Table 1. Theories Examined and Relevant Publications[3]

Theory	Relevant Publications
Organizational Politics	Franz & Robey, 1984
Structuration Theory	Orlikowski & Robey, 1991
Organizational Learning	Robey, Wishart, & Rodriguez-Diaz, 1995; Sahay & Robey, 1996; Robey & Sahay, 1996; Robey, Khoo, & Powers, 2000; Robey, Boudreau, & Rose, 2000; Robey, Ross, & Boudreau, 2002
Organizational Culture	Robey & Rodriguez-Diaz, 1989; Robey & Azevedo, 1994; Dubé & Robey, 1999; Kaarst-Brown & Robey, 1999
Dialectics	Robey & Boudreau, 1999; Cule & Robey, 2004; Cho, Mathiassen, & Robey, 2007
Actor-Network Theory	Holmström & Robey, 2005
Institutional Theory	Robey & Holmström, 2001; Cousins & Robey, 2005b
Time-Space Distanciation	Jin & Robey, 2008
Human Agency	Boudreau & Robey, 2005; Cousins & Robey, 2005a; Chu & Robey, 2008

Table 1 excludes almost all of the work on other topics throughout my career. One stream of research, however, should be mentioned for its relevance to the topic of IT and organizational change. Early in my career I was engaged with the discourse on IS development, and I treated it as a social process rather than a methodology. I was particularly interested in social conflicts between users and developers and the prospect that these conflicts could be constructively resolved to generate superior system outcomes (e.g., Robey, Farrow, & Franz, 1989; Robey & Newman, 1996).

[3] Table 1 omits foundational citations to each theory area because, in most cases, there are too many core works to include. In addition, my tendency is to draw upon a variety of works in a specific theory area rather than declare allegiance to a single author's work.

As Table 1 shows, my interest in organizational politics informs my study of IT impacts, and I thus concluded that the study of IT development and the impacts of IT could not be completely separated. Indeed, I believe that organizational changes attributed to technology originate in the process of developing and implementing systems. This observation now seems self-evident, but I only realized this connection in the 1980s, as documented in Markus and Robey (1988) and Robey (1987), and more recently in Markus and Robey (2004). This connection is re-emphasized by Leonardi and Barley (2008).

6. Taking Stock

After 40 years of effort, it is tempting to declare one's intellectual puzzle solved. The proposed solution could be stated as:

> *IT influences organizational change through its implication in social processes. Among these processes are politics, learning, institutionalization, enculturation, and others. Although social process theories are indeterminate, they provide important explanations of change by focusing on sequences of events, stages, or phases of IT initiatives.*

Although it may be selfishly satisfying now to declare the odyssey to be complete, there is at least one significant problem with the summarized solution. That is, the explanation could apply to any organizational initiative, whether IT-related or not. Thus, the organizational outcomes from initiatives for new marketing programs, human resource programs, and others could all be explained with reference to the social processes underlying their genesis, development, implementation, and use. Since we are interested in differentiating IT initiatives from other organizational change initiatives, declaring this intellectual puzzle completed would appear to be premature. We argue that a distinguishing characteristic of IT initiatives is the materiality of IT, and that materiality should be the focus of the next wave of research on IT impacts.

There are reasons why materiality has been historically neglected in research on IT impacts. For one, researchers like the first author are prone to "tilt" toward explanations that privilege the role of human agents in generating IT impacts (Leonardi & Barley, 2008; Orlikowski, 2010). Reconsidering the work listed in Table 1, it would be fair to say that it reflects the "agentic turn" in social science, or the tendency to explain organizational phenomena with reference to human agency (Hutchby, 2001)[4]. Hutchby describes this issue as the:

> *long-standing debate within the sociology of science and technology between realism (the view that worldly objects have inherent properties that act as constraints on observational accounts) and constructivism (the view that the very 'reality' of objects is itself an outcome of discursive practices in relation to the object)* (2001, p. 443).

The radical constructivist argues that humans are not bound by the design constraints of material objects and can appropriate technology as they see fit. For instance, studies that incorporate human agency (Emirbayer & Mische, 1998) as an explanatory theory suggest to some readers that IT systems can be interpreted, reinvented, or worked around regardless of system features (Volkoff, Strong, & Elmes, 2007). Yet, such an approach potentially marginalizes the role of both social structure and technology as material enablers and constraints on human action (Leonardi, 2013).

Hutchby (2001) argues that, although there is flexibility in how we interpret technology, it is not unbounded. To this end, my more recent work argues that, while human agency exercised by end users accounts for unanticipated enactments of new IT initiatives, users clearly operate in a technical and social context that constrains their chosen actions. For example, Chu and Robey (2008) attribute a decline of usage of an online learning system to the agentic choices of hospital nurses. However, the nurses' actions to minimize their use of online training was traced to the professional norms of nursing that valued traditional learning practices of sharing experiences among peers over online learning. Similarly, Boudreau and Robey (2005) attribute unintended consequences of an ERP

[4] One exception to this critique in my own work is Jin and Robey (2003), who distinguish between technical and social interfaces in an Internet startup. This distinction proved critical to understanding organizational changes as the startup company grew in size.

implementation to the exercise of human agency by staff members, who engaged in practices of informal, improvised learning involving workarounds and tweaks to overcome their limited understanding of the new system. However, formal authority ultimately prevailed to force staff to use the system as intended. These examples suggest that the tilt toward human agency may omit important ingredients of IT-related organizational change, including social structure and IT's material characteristics.

As social theory reacts to criticisms of a tilt toward human agency (e.g., Hirsch, 1997), it restores a place for social structure in the explanation of social behavior (Fuchs, 2001). Likewise, studies of IT impact can fruitfully restore a focus on the IT artifact as a central ingredient in IS research and theory (Orlikowski & Iacono, 2001; Leonardi & Barley, 2008; Leonardi, 2013). In the remainder of this paper, we offer specific guidance to researchers continuing the odyssey of studying the organizational impacts of IT with due attention to the material characteristics of IT.

7. Materiality in IS Research

In recent years, IS and organizational scholars have showed a renewed interest for studying materiality (Leonardi, Nardi, & Kallinikos, 2012). However, the approaches to studying materiality and the underlying assumptions associated with those approaches are quite varied; therefore, it is important that we clarify our core assumptions about the nature of IT's materiality (Kautz & Jensen, 2013; Leonardi, 2013). Common dictionary definitions of the root word "material" refer to matter, substance, stuff, objects, things, and so on, which suggests that materiality means tangible, physical objects such as buildings, desks, and computers. However, common definitions also include data, information, ideas, and so on, which open the range of meaning to include less-tangible artifacts such as databases, networks, and software. Both of these root meanings would seem to be relevant to understanding the materiality of IT.

Also, because they are artifacts, IT can be distinguished from concepts that are "social". Although artifacts are clearly products of social activity, they differ from the more-abstract concepts that traditionally characterize social systems: for example, structure, process, culture, norms, power, and others (Leonardi, 2013). Even computer programming languages, while potentially considered to be social in their capacity to represent objects and ideas symbolically like other human languages, are different than natural language due to their capacity to act independently of human action. This "material agency" (Pickering, 1995) is attributable to the objective properties of artifacts and natural objects rather than the interpretations or interventions of social actors.

Although we distinguish between material artifacts and social constructs, we theorize about the close relationship between them rather than tilt toward one or the other. In this way, our approach refers back to the earlier work on socio-technical systems theory. Although Orlikowski (2010) and others critique the socio-technical perspective for its historical tendency to "downplay specific technological properties and affordances, focusing primarily on human interpretations and social actions" (Orlikowski, 2010, p. 133), there is nothing inherent in socio-technical research that prohibits the inclusion of material as well as human agents in explaining organizational change. We believe that the socio-technical perspective enables us to preserve the ontological distinctions between the social and the material, just as early studies engaged with the material aspects of manufacturing and mining technologies in relation to social organization (Trist & Bamforth, 1951; Woodward, 1965). Recent studies of information technologies demonstrate the viability of a socio-technical approach in which the ontological distinction between social and technical reality is maintained (e.g., Leonardi, 2011, 2012a).

By contrast, Orlikowski favors a more radical, "sociomaterial" (without a hyphen)[5] ontology, "which rejects the notion that the world is composed of individuals and objects with separately attributable properties" (Orlikowski, 2010, p. 134; see also Orlikowski & Scott, 2008). While this approach is capable of yielding new insights into IT's entanglement with social settings (Introna & Hayes, 2011;

[5] The importance of hyphens has been discussed by Orlikowski and Scott (2008) and Leonardi (2012b). Our purpose in hyphenating the term "socio-technical" is to signal the ontological distinction between things that are social (socio-) and those that are artifacts (technical).

Scott & Orlikowski, 2013), it presents difficult conceptual challenges by displacing established ontological distinctions between social and material phenomena (Mutch, 2013). In the spirit of our professional odyssey, we advocate a socio-technical ontology (with a hyphen) because it offers the potential to learn from past lessons, especially socio-technical systems theory in organization studies. As we have argued, many organization scholars became largely mute on material aspects of organizations such as geographic location, architecture, office layout, and IT (Orlikowski, 2007). Hatch (2006), whose text includes a rare chapter on the physical structure of organizations, claims that the topic of physical structure was for many years a "theoretical backwater" in organization theory. Those who paid attention to physical objects often treated them as cultural symbols, which thus quickly shifted their focus away from the objects' materiality and toward their social interpretation (Hatch, 2006). The neglect of material features of technology seemed especially to bother Perrow in his later work. His research into technology's material failures at the Three Mile Island nuclear power plant, which suffered a meltdown of its reactor core in the 1970s (Perrow, 1981), suggests a much different and more tangible role for technology than he theorized earlier. He also contributed an essay on the material consequences of human factors engineering for organizations. Perhaps to compensate for his role the earlier de-materialization of technology in organization theory, Perrow wrote:

> *I hope I have suggested that organizational theorists pay attention to the way mere "things"—equipment, its layout, its ease of operation and maintenance – are shaped by organizational structure and top management interests, and in turn shape operator behavior. The early work on technology and structure, including my own, recognized a one-sided and general connection, but it failed to recognize how structure can affect technology and speculate about the large areas of choice involved in presumably narrow technological decisions* (Perrow, 1983, p. 540).

The socio-technical approach has been taken up in recent studies, for example the study by Whyte (2013), who demonstrates the problems inherent in using digital representations to support architectural design practices in high-risk, large-scale construction projects. Likewise, Jonsson, Holmström, and Lyytinen (2009) show the effects of remote diagnostic systems on boundaries between equipment suppliers and maintenance departments in client firms and found that technology features are directly implicated in boundary spanning through equipment monitoring tasks and preventive maintenance interventions. These studies and others (e.g., Østerlie, Almklov, & Hepsø, 2012), through their engagement with the materiality of IT and the physical world, suggest that traditional views on IT's social impacts can be revised to capture the influence of IT's material properties.

In the following sections, we contribute to the growing discourse on materiality and organizational change first by assessing the concept of technology affordance. We show affordance to be consistent with a relational ontology due to its dependence on the relationship between material objects and human actors. Second, we demonstrate how materiality can be incorporated into organizational routines theory (Feldman & Pentland, 2003), an established theory used to explain organizational persistence and change.

8. Understanding Affordances

Various scholars have advocated the use of affordances for theorizing technology (Faraj & Azad, 2012; Hutchby, 2001; Leonardi & Barley, 2008; Markus & Silver, 2008; Norman, 1988) and incorporated the concept into their framing of IT's relationship to new organizational forms (Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007). The concept of affordance originated in the field of ecological psychology (Gibson, 1977, 1979) and is used to define the possibilities and limits for action that a material object offers to an actor. As such, the concept supports a functional explanation of how material objects are implicated in human activity. Stinchcombe (1968) argues that functional explanations of social phenomena involve a type of reverse causality wherein the consequences of human activity help to explain the presence of social structures and technologies that produce them. For IT artifacts, this means that they exist because a particular functional need was identified for which the artifact was designed and implemented. However, this does not mean that the intentions of an IT artifact's designer are always realized in use or that a designer's intentions are understood or

shared by the artifact's users. Rather, selected IT features can be used and others ignored or worked around by human agents with their own purposes in mind. Thus, social consequences, both anticipated and unintended, are realized through the functionality of material artifacts that "afford" those consequences.

Norman's (1988) use of affordance represents an early effort to theorize materiality in the design of human-computer interfaces. However, it also demonstrates the ease with which a concept intended to refer to materiality of IT can become "constructivist" in practice. Norman's intention was to highlight the need for technology designers to make technology's possibilities for action (i.e., the affordances) apparent to users. He later acknowledged that: "I should have used the term 'perceived affordance', for in design, we care much more about what the user perceives than what is actually true" (Norman, 2002, p. 1). This confession suggests regret over a rather loose usage of the term and the corresponding need for researchers to exercise care in adopting concepts from other disciplines. In fact, there are several issues with the concept of affordance that we chronicle in the following review of the concept's origins and subsequent development within the field of ecological psychology.

Gibson (1977, 1979) coined the term affordance and included it as a core concept in his theory of ecologically based visual perception, which explains how organisms perceive and interact with their environments. For Gibson, explanations of visual perception needed to include both the affordances of the external environment and the psychological process housed within the individual:

> *The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. …I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment* (Gibson, 1979, p. 127).

Gibson developed his affordance concept in response to cognitive psychologists who argued that meaning only exists in the mind of the perceiver, which would make perception a wholly internal mental process. Gibson countered this extreme constructivist argument by theorizing that affordances represent meaning that exists in the environment itself and could therefore be directly perceived. This means that the possibilities for action provided by material objects (i.e., their affordances) exist independently of the organism's perception as long as information is available in the environment that could be perceived. In other words, the affordance relationship exists as long as action possibilities are perceivable, but the relationship remains even when we do not focus on action possibilities. From this perspective, Gibson's concept of affordance differs from a strict "feature-centric" view, which shifts attention toward specific material objects and away from the relational view favored by both socio-technical and sociomaterial approaches (Faraj & Azad, 2012). For example, a flight of stairs that is proportional to the length of a person's leg affords climbing; but when a person perceives whether s/he will be able to ascend a set of stairs, s/he directly perceives the affordance of climbability rather than the specific riser height of the stair (Warren, 1984).

In the ensuing debate in ecological psychology over ontology, no universal definition of affordance emerges. Stoffregen (2003) groups the opposing perspectives on affordance into two categories. One perspective holds that affordances are properties of the environment (Michaels, 2000; Reed, 1996; Turvey, 1992) while the second holds that affordances are relations between an animal and its environment (Chemero, 2003; Warren, 1984; Stoffregen, 2003). Gibson's position, which was not completely developed in his own writings, has been interpreted as representing the first perspective. Following this lead, Turvey (1992) defines affordances as dispositional properties of the environment that pose "real possibilities" for action. Dispositions are equivalent to laws; that is, "an invariant relation between or among substantial properties of things" (Turvey, 1992, p. 177), and therefore allow for prospective control of action, which Turvey considers essential to an accurate ontology of behavior. In addition, as properties of the environment, dispositions require a complementary property of organisms that Turvey calls effectivity. The presence of a disposition and an effectivity together result in the actualization of a related behavior.

Stoffregen (2003) represents the contrasting relational perspective by arguing that affordances cannot be dispositions because one of the characteristics of dispositions is that, in the presence of suitable circumstances, dispositions never fail to be actualized. Stoffregen argues that affordances cannot be dispositions because they do not always result in specific action by a related organism. Stoffregen suggests that this problem can be overcome by conceptualizing affordances as emergent relational properties of an animal-environment system. This perspective, he argues, eliminates the need to consider properties of the environment (i.e., dispositions) as separate from properties of animals (i.e., effectivities). Rather, the animal-environment system becomes the unit of analysis, thereby allowing affordances to be specified and detected prospectively and preserving the notion of prospective control proposed by Turvey (1992).

Stoffregen's (2003) conceptualization of affordances appears to parallel Orlikowski's (2007, 2010) position that focuses on the ways in which the social and material intertwine in ongoing, situated practice rather than treating them as distinct concepts. Therefore, Stoffregen's definition of affordances can be characterized as a sociomaterial concept that encompasses both material objects and actors. IT research that views IT impacts as performative outcomes of a "sociomaterial nexus" (Introna & Hayes, 2011) would appear to find support for the positioning of affordances at the actor-system level.

Although, Stoffregen (2003) argues for a relational ontology of affordance, there are further controversies among scholars who take the relational perspective. This debate seems to parallel the differences between IT researchers who adopt the sociomaterial approach and those who adopt a socio-technical approach. In ecological psychology, Chemero (2003) represents the latter view and defines affordances as "relations between the abilities of animals and features of the environment" (p. 189). Chemero's approach differs from Stoffregen's (2003) because it defines affordance as a relationship between two distinct entities rather than as a property of an emergent system. Chemero's justification for defining affordances as relationships is based on Heft's (2001) argument that Gibson's ecological psychology is descended from William James's radical empiricism. According to radical empiricism, everything that is experienced is equally real. Among the things we experience are relations between things, so relations become real, with the same status as the things that stand in relation. In this view, affordances become real possibilities for action that depend on both the material properties of objects and the ability of actors to perceive and use them. Material properties thus become necessary conditions for affordances, but are not the affordances themselves (Markus & Silver, 2008).

The ontological issues raised above have direct implications for the use of affordances in IT impact research. For example, defining affordances as properties of the environment would require the detailed specification of affordances associated with specific IT hardware and software, which raises questions regarding the requisite level of detail. Would hardware plus software constitute "features", or would features imply too much of a relationship with a prospective user? Should we focus on the broad features afforded by major systems (e.g., Zammuto et al., 2007) or dig deeper to identify affordances of embedded sub-features? These questions are consistent with an "essentialist" position that contrasts with a "relativist" stance that is more familiar to social scientists who study IT and organizational change. In our own research (Anderson, 2011), we have theorized material artifacts in terms of their affordances using a relational perspective that preserves ontological distinctions between artifacts and social entities.

Our discussion of affordances is meant to place the ontological debate among IT researchers in broader perspective. There are numerous challenges inherent in adopting new concepts in the study of IT's organizational impacts. Adding the material characteristics of IT to the mix has been widely advocated, yet concepts like material agency (Pickering, 1995), imbrication (Leonardi, 2011; Introna & Hayes, 2011), and sociomateriality (Orlikowski & Scott, 2008) require careful unpacking. Clearly, researchers investigating the materiality of IT and organizational change need to understand the issues underlying their theoretical choices.

Our discussion of affordances has traced the concept back to its origin in ecological psychology, where ontological debates appear to parallel those occurring between the proponents of different positions for studying the materiality of IT and its organizational consequences. Although IS

researchers have worried for years about producing novel theory and a distinct legitimate identity for IS (Benbasat & Weber, 1996; King & Lyytinen, 2006), most useful ideas such as affordances can be traced back to related disciplines. In many cases, however, existing theory needs to be revised to include material aspects of IT that may have been marginalized in the theory's initial formulation. In the following section, we examine an established theory used to explain organizational persistence and change, organizational routines theory (Feldman & Pentland, 2003), and show how it can be extended to include material artifacts.

9. Theorizing Materiality in Organizational Routines

Routines are a core component of any organization, so they comprise a natural focus for studies of IT impacts on organizations. Feldman and Pentland (2003) define organizational routines as repetitive, recognizable patterns of interdependent actions carried out by multiple actors. Although routines are generally associated with stability and inertia, they are also a source of flexibility and change. A routine may contribute to organizational inertia if it re-enacts an established pattern of action, but each performance of a routine may generate new patterns of action (Feldman & Pentland, 2003), making this theory relevant to the study of IT and organizational change.

Feldman and Pentland identify two aspects of organizational routines: the ostensive and the performative aspects. The ostensive aspect embodies the abstract, generalized idea of the routine: the routine's ideal or schematic form, which may be codified as a standard operating procedure or exist as a taken-for-granted norm. The performative aspect consists of the actual performances of the routine and is inherently improvisational. Feldman and Pentland argue that neither aspect alone is sufficient to describe the properties of organizational routines. They treat routines as "generative systems" capable of producing a variety of performances, each of which is partly (re-)enacted from past experience and partly improvised based on current circumstances and future goals (Pentland & Feldman, 2008).

Although IT artifacts are, in practice, often implicated directly in organizational routines (D'Adderio, 2008; Volkoff et al., 2007), Pentland and Feldman (2005, 2008) expressly exclude them from the definition of routines and thus marginalize the material aspects of IT artifacts. Although IT artifacts may embed a vision of organizational work processes and coordinate interdependent activities, they are theorized as external to routines (see Figure 1). IT artifacts may have the capacity to influence and represent routines but do not have the capacity to become part of the generative system, according to Pentland and Feldman (2008).

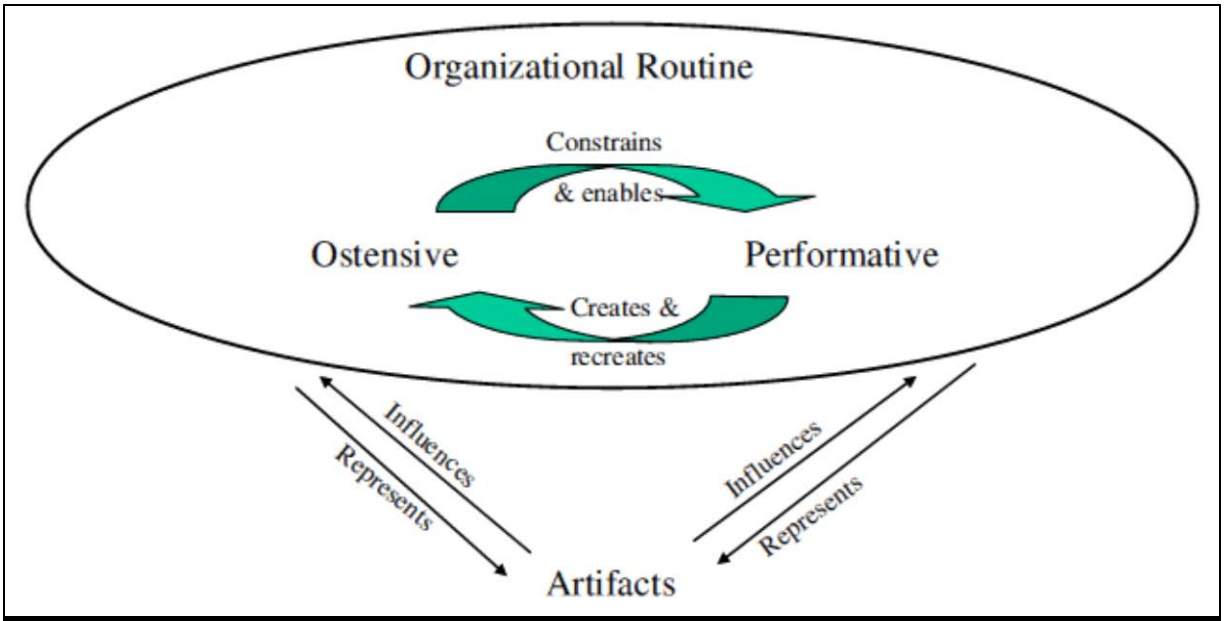

Figure 1. Organizational Routines as Generative Systems (Pentland & Feldman, 2008, p. 241)

We find this exclusion to impede the use of organizational routines theory to study the relationship between IT and organizational change. Along with D'Adderio (2008, 2011), we strive to theorize IT artifacts as important constituents of the generative system of organizational routines (Raymond, 2012). We develop two related arguments. First, some (not all) IT artifacts can become embedded into organizational routines to the point where it becomes unlikely that the routine could be performed without the artifact's presence. Second, once embedded into routines, IT artifacts become parts of the generative system that Feldman and Pentland (2003) define as an organizational routine.

Artifacts become embedded into organizational routines through a process of adaptation and selection, similar to the way that IT applications are appropriated as described by adaptive structuration theory (DeSanctis & Poole, 1994). Although human actors performing a routine may be provided IT artifacts, and perhaps mandated to use them, artifacts may be discarded, ignored, used merely as accessories, or become embedded into the routine. This produces a range of possibilities, from no influence to full influence, by which artifacts can shape and be shaped by the performances of organizational routines (D'Adderio, 2011). For example, human agents performing an accounting routine may decide to discard, ignore, or use a calculator as a mere accessory since the accounting routine could be performed without its presence. By contrast, an accounting software package is more likely to become embedded into an accounting routine because calculations performed outside the software would be excluded from formal reports.

As described earlier, material agency is the capacity of artifacts to act independently of humans (Pickering, 1995). Many artifacts, and natural objects, have objective properties that are capable of exerting agency on their own, rather than depending on the interpretations or interventions of social actors. Many routines can be performed by material agents alone. For example, software programs may perform as material agents by updating databases each night without direct human oversight or intervention. Many routines involve both IT artifacts and human interaction, so their performance requires material and human agents to interact closely (Leonardi, 2011, 2013). Rather than excluding such commonplace phenomena from the basic definition of routines, we seek to include them.

Feldman and Pentland (2003) argue that both the ostensive and the performative aspects of routines can produce organizational change through specific functions or roles. We extend their theory to include IT artifacts embedded in organizational routines as parts of the generative system that can produce organizational change. We argue that embedded IT artifacts are not merely external or invariant influences on routines, as suggested in Figure 1, because they can play roles similar to those played by the ostensive and performative aspects of organizational routines. Thus, embedded IT artifacts may contribute to the varying and indeterminate performances that are characteristics of generative systems.

Just like the ostensive aspect of routines, embedded IT artifacts can play a guiding role for human action in organizational routines. In a guiding role, an IT artifact serves as a guide or template by enabling and constraining human action while not determining performances, which always remain open to human choice (Feldman & Pentland, 2003). By incorporating organizational elements such as routines, data, and roles, IT artifacts serve as a template for behavior by influencing what actions ought to be taken (Volkoff et al., 2007). However, while Feldman and Pentland treat the ostensive aspect of routines as a social construct, guiding what should or should not be done, material IT artifacts embedded in organizational routines are capable of constraining human action by requiring certain actions and preventing others. For example, Pentland and Feldman (2008) found that the implementation of a new software package redefined who could perform certain tasks and changed the specific actions required by human agents. Moreover, because IT artifacts often integrate interdependent work processes, human agents may be constrained by the actions of other users. For example, ERP and workflow systems constrain human agency by limiting the actions permitted of linked users to ensure coordination and consistency across interdependent work processes. Although users can choose to bypass the software, their boycott carries the risk that their work will not be accepted by others in the organization (D'Adderio, 2011). Furthermore, embedded IT artifacts enhance control by making routine performances more visible or transparent across an organization. Embedded IT artifacts can monitor the performance of organizational routines, identify aberrant

actions that require correction, and enforce compliance to standard procedures. In addition, embedded IT artifacts can play a legitimating role for human action in organizational routines. IT artifacts can codify the organization's values, norms, and standard procedures by incorporating interests, intentions, assumptions, rationales and logics (D'Adderio, 2011). If top management mandates human agents to use specified IT artifacts to perform their tasks, compliance with such mandates legitimates organizational routines.

Just like the performative aspect of organizational routines, embedded IT artifacts may contribute to the production of varying and indeterminate routine performances as material agency interacts closely with human agency in the performance of routines (Leonardi, 2011). As material agents, embedded IT artifacts offer functional affordances to human agents to appropriate, work around, and enact in ways that may deviate from the ostensive templates and inscriptions. New affordances may be perceived and used over time as human agents experiment with embedded IT artifacts, discovering new features that afford different kinds of human action. This observation is consistent with our relational view of affordances, as organizational routines may be seen as possibilities for human action that depend on both their material properties and the ability of human agents to perceive and use them.

By these arguments, we hope to demonstrate how material IT artifacts embedded in organizational routines can contribute to the generation of varying and indeterminate routine performances. Acknowledging the material aspects of organizational routines helps to explain both their stability and flexibility without exclusive reference to human agents. By treating embedded material IT artifacts as part of the generative system of organizational routines, researchers may be less inclined to treat IT as an external or invariant influence on organizational routines. For example, by treating accounting software packages as part of a generative system within accounting practice, researchers may be less likely to hypothesize a deterministic "impact" of IT on accounting and more likely to attend to the socio-technical practice of accounting.

Including IT artifacts in this way extends organizational routines theory in ways that potentially enhance its explanatory power. Through their material presence, embedded IT artifacts are capable of enforcing specific patterns of action while, at the same time, human agents are capable of appropriating those artifacts in different ways. Over time, resulting routine performances can reinforce enduring routines and/or lead to novel organizational changes. Integrating IT's materiality in established theory thus promotes greater sensitivity to the close interdependence between material and human agencies.

10. Conclusion

Theorizing IT artifacts in material terms should help to redress the neglect of material characteristics in IT impact studies. Our historical odyssey spans the first author's entire career and the beginning of his co-authors' careers. The historical treatment of technology in organization theory demonstrates how easily, and perhaps inadvertently, material aspects of organizations and technology can float into the backwaters of theory development. Oddly, material properties of work settings have always been salient, yet they somehow have escaped the attention of some researchers. Perhaps the ubiquitous nature of IT contributes to obscure our appreciation of materiality's importance. We believe it is past time to engage with the material IT artifacts that are at the heart of inquiries into the effects of IT on organizational change.

In advocating our socio-technical approach to studying affordances and routines, we acknowledge some challenges. The concept of affordance shows its roots in psychology by emphasizing the relationship between a single actor and specific material objects. To be useful in explaining organizational change, the affordances that material artifacts offer must be conceptualized at a higher level of analysis than the individual. They must "scale up" to describe the relationship between aggregated technologies and larger social collectives. This ambition is reflected in Zammuto et al.'s (2007) advocacy of affordance as a construct applicable to major types of IT applications and organizations as a whole. Presently, studies of remote sensing technologies (e.g., Westergren &

Holmström, 2012; Østerlie et al., 2012) could use affordances to theorize how material objects offer action possibilities to work teams and organizational units. Without such extensions, the concept of affordance may remain explanatory at the individual level of analysis only.

A second challenge is to specify how material artifacts offer explanations of phenomena that we would not otherwise understand. Our aim is not to simply include materiality because of its neglect in prior explanations, but rather to learn more about the complex processes of organizational change. To this end, material artifacts need to be granted status as theoretical concepts that help to explain organizational change. In our efforts to include material artifacts as part of the generative system of organizational routines, for example, we acknowledge the different capabilities of social actors and embedded material artifacts (Raymond, 2012). Thus, it matters whether particular activities in a routine are performed by social actors, material artifacts, or both. Understanding the relationships between material and human agency is an important aspect of previous work by Pickering (1995) and Jones (1999), who have theorized the relationship between material and human agency as a "mangle." The more recent studies by Leonardi (2011, 2012a) and Martini, Massa & Testa (forthcoming) demonstrate the value of attending to the unique characteristics of social and material artifacts and their exercise of agency.

Although it is well beyond the purpose of this paper to prescribe methodological guides for investigating material artifacts, one simple principle can be offered. Researchers committed to theorizing about the materiality of IT need to engage directly with IT artifacts and the surrounding material environment of organizations in their studies. For example, Anderson's (2011) study of nursing practice engages not only with the features of the new IT system introduced by the hospital but also the physical surroundings of patient care, including the size and mobility of carts designed for mobile computing devices, the location and security of medicine dispensary cabinets, and the space within patient rooms. Human agents interact with all of these material artifacts in their work practice, suggesting that IT researchers include non-IT material artifacts as well as IT systems and technology.

In closing, we hope that our analyses of affordances and routines provide good examples of attempts to theorize materiality in research on IT's organizational impacts. As the discourse on sociomateriality and socio-technical systems progresses, we hope that our experiences in working with these concepts helps to stimulate new ideas while honoring insights from past research and theory.

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About the Authors

Daniel ROBEY is Emeritus Professor of Information Systems at Georgia State University. He received his Doctorate in Business Administration from Kent State University. His work has appeared many journals in information systems and management. He received the 2009 LEO award bestowed by the Association for Information Systems and the International Conference on Information Systems for a lifetime of distinguished contribution. He also received the Lifetime Service Award from the Organizational Communication and Information Systems Division of the Academy of Management in 2010. He is Editor in Chief of *Information and Organization*.

Chad ANDERSON is an Assistant Professor of Information Systems at the University of Nevada, Reno. He received his Ph.D. from Georgia State University in 2011 and holds an MBA from Eastern Kentucky University and Bachelor of Science degrees in Occupational Therapy and Psychology from Eastern Kentucky University and Business Administration from North Dakota State University. Chad's research interests include health informatics, materiality, and scientometrics and his work has been published in *MIS Quarterly*, *Communications of the AIS*, and the *Journal of Organizational and End User Computing*.

Benoit RAYMOND is Assistant Professor in the Department of Organizational Information Systems at Université Laval, Canada. He received his PhD in Computer Information Systems from Georgia State University in 2010. His research interests include the organizational and social effects of IT with an emphasis on organizational routines and the materiality of IT artifacts. His dissertation examined how IT artifacts influence the design and performance of organizational routines and he is currently doing research in this area. He co-authored a chapter in the book *Materiality and Organizing* (Oxford University Press, 2012) and his work has been published in AMCIS 2011 Proceedings and the *Journal of Applied Ergonomics*.