MIS Quarterly

THEORY AND REVIEW

TECHNOLOGY AS ROUTINE CAPABILITY[1]

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While technology is most commonly associated with material things, tools, or artifacts, it is also associated as a concept with routines, patterns of action that provide capabilities. Researchers have struggled to bring these interpretations together. Drawing from Schatzki's practice theory, we offer an overarching perspective that ties tools as devices to routines in a broader social context, yielding insights into what is termed ***technology as routine capability*** *in the advancement of practices. How change in technology occurs both within and among practices is examined from this perspective. Four principal* ***modes of change*** *are identified: (1)* ***design****, in creating new devices and routines; (2)* ***execution****, in operating devices and performing routines; (3)* ***diffusion****, in spreading devices and routines to a population's members; and (4)* ***shift****, in adapting devices and routines to change among a world's practices. Change is seen to be closely intertwined among the modes, suggesting that future research examine cross-modal change, in particular, to gain a better understanding of how new technology advances practices. Overall, our new perspective provides a lens that ties together previous strands of research, allowing insights from multiple studies to accumulate in a way that both illuminates and motivates further work. Enlarging on current interpretations, it suggests that routines are integral to technology itself.*

Keywords: Technology, artifacts, routines, practices, technological change, information systems, affordances

Introduction

As a thought exercise, imagine a Paleolithic man, Brian, with no technology, not even a laptop. Hungry, Brian seeks repeatedly without success to pry open a walnut. Frustrated, he reaches for a nearby right-sized rock and crushes the nut. Turning a summersault in joy, Brian repeats the action, opening more walnuts with increasing skill. Voila! A new technology discovered in the early Stone Age. Question: Which came first, the tool or the routine? Not that Brian would have paused to reflect on this!

Here we do reflect and suggest a refinement in how we think about new technology, arguing that a fruitful understanding hinges on our corresponding grasp of tools and routines, and, in particular, their relationship to each other. We explore this relationship in the context of modern information technology (IT), motivated by the now commonplace observation that our world is increasingly saturated with technologies, more digital than traditionally physical, many of great consequence for the transformation of practices across industries and professions (see Yoo 2013). We seek to gain perspective and new understanding of how all this has come about in the interplay of tools and routines since the Time of Brian.

We know that we're not alone in this and much has already been said, by technologists, sociologists, economists, historians, and philosophers (see Bijker et al. (2012), with a new preface to a classical work). Still, we would agree with Arthur (2009), that we lack adequate theory of technology and how it changes, in particular in the context of IT. Here, following Arthur's lead, we seek to gain perspective on this issue and focus in particular on the role of routines, understood as repeated patterns of action in organizational contexts (Pentland and Feldman 2008). Drawing selectively from a fragmented literature, our aim is to bring routines to the foreground of the broader technology story, as we believe

[1]Youngjin Yoo was the accepting senior editor for this paper. Brian Pentland served as the associate editor.

they deserve a more prominent position than commonly given, even by many routine theorists. Indeed, we believe routines are integral to technological change, in a way that expands on current understandings. Here we develop a new perspective that explains how.

Tools have thus far dominated, perhaps because many are physical, real to our eyes, and too because they provide a historical trace after being rediscovered, as with Stone Age tools. Thus, while technology is an umbrella term with a variety of usages, it is most commonly associated with stuff—material things, tools, or artifacts (Orlikowski and Iacono 2001). At the same time, that technology may at its core entail more than devices has come to be recognized by practice-oriented researchers, who still struggle as to how best to understand it, and where routines may or may not be seen as central to the interpretation (see Leonardi et al. 2012).

Here, seeking a new understanding, we suggest that technology is as much if not more about what we are collectively able to *do* with our devices, by means of our routines, than with the devices themselves. We develop an overarching perspective to elaborate on this, building from the practice-oriented work of others. In contrast to the view of *technology as device*, we offer a view of *technology as routine capability*. Contrary to literature equating technology to devices, we argue that device-enabled routines constitute technology, in terms of capabilities achieved in human practices. Devices must, in effect, be "wrapped" in routines in the constitution of technology.[2] *Routines are seen as integral to technology itself.* New technology advances human practices, and fuses new routines and devices to provide new capabilities. The story of technological change unfolds around this overarching view, which allows for both "zooming in" within a practice and "zooming out" among multiple related practices (Nicolini 2009). Routines serve as the linchpin in the story and receive a fresh interpretation that enables change to be understood in a new and unified way, where it can be aggregated and disaggregated, coalescing insights across traditional research boundaries. The key here is the view of practices as constituted from routines, facilitating the examination of whole practices in terms of routines. The gain is a new theoretical and meta-analytic framework that allows insights from multiple studies to accumulate in a way that both illuminates and motivates further research on technological change.

In what follows, we elaborate. To establish focus, we first consider the technology as device perspective and the problems associated with it, and how these problems are addressed or not in the existing practice-oriented literature. Building on certain of this work, we then introduce the notion of technology as routine capability, drawing upon Theodore Schatzki's (2002) practice theory to develop a new overarching perspective. From this vantage point, we consider change in technology and what brings it about, and how it may be understood, not only as change in devices, the prevailing view, but to greater advantage, as change in routine capabilities which advance practices in worlds of constant flux. We apply the perspective to ERP (enterprise resource planning), revisiting what is known from research about how it came to be widely adopted, seeking to gain further illumination, but also to other illustrative technologies. We conclude by drawing the implications for future research.

Technology as Device and in Use

The technology as device perspective gains its fullest treatment in Brian Arthur's (2009) treatise on the nature of technology and its relationship to the economy. Arthur takes a broad view of technology as a "means to fulfill a human purpose," a "method or process or device" (p. 28). Building from a set of fundamental principles, the first of which is that "technologies, all technologies, are combinations .... constructed or put together—combined—from components or assemblies or subsystems at hand" (p. 23), Arthur portrays technological change as a process of combinatorial evolution. He discusses technological domains ("bodies of technology" that constitute toolboxes for building particular devices, p. 71); engineering practice (in designing and constructing devices and methods, p. 90); novel technologies and how they arise (a radically new technology uses a principle new to the purpose at hand, p. 108); a technology's ongoing development (and how it eventually reaches maturity, p. 138); redomaining (where a new body of technology displaces an older one, as with quartz crystals in clocks); technology evolution (where human and technical needs create *opportunity niches* for new technology); and the economy as an expression of the technologies employed (a dynamic, generative economy, where every new technology as a solution contains the seed of another problem, carrying things forward, p. 200). From an evolutionary economics perspective, Arthur essentially theorizes how technology has come to permeate all aspects of our lives.[3]

On the whole, Arthur's theory is appealing and persuasive, and we will make further reference to it. But as seen here,

[2]I thank the Associate Editor for suggesting the use of this metaphor.

[3]Swanson (2017) explores the application of Arthur's theory to information systems.

while it allows for a broader interpretation, it is built and presented largely around technology as devices, inclusive of both hardware and software in a digital context.[4] Much attention is given to the *engineering* of these devices, and rather little to their actual *use*. While the role of devices is well described, devices are characterized as in and of themselves *executable*. No distinction is drawn between devices and their means of execution in human settings, namely, we argue, routines. Rather, Arthur blends these concepts, suggesting that devices somehow "embody" a sequence of operations for executing their functionality (p. 31). We claim instead that most such operational sequences are generated in the broader execution of routines serving human practices. They are not the province of the devices alone.

A basic engineering view is similarly taken by Norman (1990), who draws from Gibson (1986) to suggest that well-designed devices provide prospective users with *affordances* that enable functionalities (see also Gaver 1991). We agree here with others (e.g., Faraj and Azad 2012; Leonardi 2011; Markus and Silver 2008) who have challenged the notion that devices in and of themselves incorporate affordances, independent of their actual use, suggesting instead a relational view, where affordances somehow "exist between people and an artifact's materiality" (Leonardi 2011, p. 153). Taking a similar but distinct view, we argue here that to the extent that devices offer affordances, it is through the routines that employ them. We elaborate below.

A substantial practice-oriented literature, much of it with origins in the social construction of technology (Bijker et al. 2012), argues in opposition to the technology as device perspective, suggesting instead that technology is a form of social materiality, while taking a wide range of theoretical stances. Interest often centers on the deep philosophical issue of material versus human agency, where traditional humanists have been challenged by "post-humanists" who have brought machines to the forefront of the interpretation.[5] In particular, Latour's (2005) seminal actor–network theory (ANT) brings the notion of action forward, and provides a useful analytic lens for studies of interaction among actants, both human and machine. Research taking a basic practice view (Orlikowski 2000; Orlikowski and Scott 2008, 2013) distinguishes between technology as device and technology in use, interpreting the latter as *sociomaterial assemblages.* While concerned with "capacities for action" (Orlikowski 2009, p. 11), this work tends not to feature routines as a central concept in its mostly micro-situated interpretations.[6] Here, seeking an extended understanding, we argue that such capacities as capabilities are achieved fundamentally by routines.[7] We build on the philosophical foundations provided in Schatzki (2002), which resolve the agency issue in the context of human practices.

Recent related research, Leonardi (2011) and Pentland and Jung (2016), takes a sociomaterial view close to our own, describing how technologies as devices are often intertwined with routines that employ them (Pentland and Feldman 2008). However, in these interpretations, technology is equated to devices, perhaps inadvertently perpetuating the technology as device perspective. We argue (with others, for example Robey et al. 2013) that this research rightly maintains a distinction between devices and routines. However, the basic routine view should be extended to embrace technology as a form of routine capability, where devices receive their identities as such through affordances built in routine performance (as with Brian's rock), and where routines themselves are constructed as components of broader practices subject to transformative change.[8] We build this new perspective next. Table 1 summarizes and previews where we are going, showing how we build from basic alternative views of technology in terms of five concepts central to our own view.

Routine Capability

We introduce here the expanded notion of technology as *routine capability*, by which we simply mean the capability associated with device-enabled routines. Usually this entails the accomplishment of some *task*. That routines provide for such capabilities is well established in the literature, though often without much elaboration.

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[4]Arthur points out that a software method, such as an algorithm, requires hardware to carry it out and constitutes a device in its employment (pp. 30-31). As seen here, software in the form of either code or data necessarily has a material representation in which it may be seen as a device.

[5]For a recent collection of critiques and commentary in the IS context, see Hassan (2016).

[6]The notion of sociomaterial assemblage offered in Orlikowski and Scott (2008, p. 457) also sidelines the concept of affordance, associating it with an earlier and different research stream.

[7]Cecez-Kecmanovic et al. (2014) provide a recent review of sociomateriality in the IS context. Leonardi (2013) suggests that a practical perspective is one in which the distinction between a device and its use is maintained, where the understanding is that "the materiality of a technological artifact affords certain uses and actions" (p. 70). We build from this fundamental notion.

[8]The idea that technology itself embraces not only material devices and their engineering, but their use, has deep philosophical roots. See Lawson's (2008) discussion of technology in terms of its "concern with the extension of human capabilities" (p. 2). Also see Mitcham (1994).

Table 1. Five Central Concepts in Alternative Views of Technology				
Central Concepts	**Basic Engineering View**	**Basic Practice View**	**Basic Routine View**	**Routine Capability View**
Devices	Technology as device	Technology as device	Technology as device	Device as routine component
Affordances	Device property	Not featured	Built in routine performance	Built in routine performance
Routines	Not featured	Not featured	Routine as pattern of action	Routine as practice component
Capabilities	Not featured	Not featured	Not featured	Technology as routine capability built in practice
Practices	Not featured	Technology in use as sociomaterial assemblage	Not featured	Practices as constituted from routines and capabilities

Note: The routine capability view features five central concepts featured or not in three alternative views (plus the concept of worlds, not shown). Where a concept is not featured, this does not imply that it is altogether absent, as it may be latent and sometimes surfaced. The present portrayal shows only how the routine capability view draws from and extends the alternatives to facilitate the understanding of broad change in technologies and practices.

Routine theory has its origins in the classic work of Simon (1947), March and Simon (1958), and Cyert and March (1963), which characterizes routines as efficient means of organizational coordination. That routines embody "know-how" and are fundamental to firm capabilities, the range of things a firm can do, was advanced by Nelson and Winter (1982), who proposed that innovation in capabilities occurs through gene-like recombination of existing routines.

Much subsequent research, centered on the firm, takes this "capabilities" perspective of routines (Parmigiani and Howard-Grenville 2011). But in this work, certain routines and capabilities have come to be seen as more important than others. Strategy research, addressing competitive advantage, has focused on what is termed dynamic capabilities, more than on routine capabilities, associated with operations, interpreted as "ordinary" (see Teece et al. 1997; Winter 2003).

But if many routine capabilities provide no competitive advantage, they are no less socially or economically important simply because most firms share them. On the contrary, such rough parity may more or less define what it means for an industry to possess a technology. An industry advances when most its members bring themselves up to speed, not just when one innovates early, seeking an edge. Industry and professional associations are thus often active in promoting new technologies and standards seen as important to all (see Markus et al. 2006).

Here we are interested in routines and capabilities that come to be widely shared. We draw from the practice perspective of routines in the literature, which, in contrast to the capabilities perspective, focuses on the routine itself, opening up its "black box" to examine its operation (Parmigiani and Howard-Grenville 2011). Here routines embody "grammars of action" among individuals engaged in effortful accomplishment (Pentland and Reuter 1994). Too, routines undergo continuous adaptation and can be a source of organizational innovation (Feldman and Pentland 2003). Routines emerge in performances and are much more than "things," as Feldman et al. (2016) show in recent studies of routine dynamics, which extend the basic routine view. In particular, routines are constitutive of structures and practices beyond themselves, such as those of professions (Feldman 2016). Here we suggest that routines can be fruitfully understood as constitutive of technology.

Following Pentland and Feldman (2008), we understand routines to be patterns of action, by people, but also machines. Having both ostensive and performative aspects, routines typically employ devices, some as actants (Latour 2005), as with software that mediates the work of different organizational users (D'Adderio 2008). We observe that many, if not most, devices are employed only through routines, even while others serve as embedded components. To the extent that many devices offer affordances, it is largely through the routines that employ them.[9]

[9]Embedded component technology is exemplified with microchips and batteries in the many IT devices they serve. The evolution of devices reflects not only their uses, but corresponding evolution in their embedded components. Arthur (2009) provides an excellent discussion.

Human Practices

Routines also have their purposes. These may go unseen within the opened black box of the singular routine. How the task served by the routine fits into a larger scheme of human activity may go unaddressed in the basic routine view. Here, consistent with new research examining relationships among routines, we seek to remedy this.[10] We establish a bridge between the capabilities and practice perspectives. We borrow from the traditional association of capabilities with firms and associate them instead with practices. We argue that a technology, as a routine capability, serves to advance a *human practice*. The concept of human practice is given a broad interpretation and understood to entail a family of routines executed in coordination, and, to some extent, socially in common. An organizational example is university administration, with its recent attempts to apply IT to faculty hiring, and promotion and tenure routines currently mired in paperwork. Human practices also include those by individuals, for example, consumers, in collective contexts such as shopping, where multiple routines are typically called upon and coordinated as needed.

The notion of practice is a rich one in the literature, especially in social philosophy (see Pickering 1993; Schatzki 2002, 2011; Schatzki et al. 2001). As a perspective that embraces a panoply of social theory and interpretive research approaches, it has been widely applied in organizational studies, including those of routines, as just discussed. It has also motivated considerable IS research (see Cecez-Kecmanovic et al. 2014; Jones and Karsten 2008; Wagner et al. 2010). Here, to advance theory, we tie the notion of practice explicitly to the notion of routines, while also differentiating it. We rely specifically on Schatzki's (2002) deeply informed practice theory as presented in his book, *The Site of the Social*. Schatzki illustrates his "social ontology" in part by applying it to an IT-based practice of interest, namely, day trading on the NASDAQ, to which we will make reference.

Schatzki observes that "social life is plied by a range of such practices as negotiation practices, political practices, cooking practices, banking practices, recreational practices, religious practices, and educational practices" (p. 70). He defines practice as "a bundle of activities … an organized nexus of actions," themselves "a set of sayings and doings" manifested in tasks and projects (p. 71). The notion of tasks, grounded in actions, tracks closely to that of routines and will be interpreted here as such. (Strictly speaking, this constitutes a narrowing of Schatzki's notion of tasks, which includes non-routine ones, in his terms. Our own notion of routines is a broad one, allowing for reformation when faced with the non-routine.)

By *advancing* a human practice, we mean achieving a more favorable social position for it. This often entails improving upon its economics, social acceptance, or politics, simplifying it or otherwise reducing its costs, for instance, or finding new outlets for it, expanding its presence, or increasing its appeal, making it more enjoyable, or obtaining favored social treatment for it, or improving its reputation. A rich array of purpose thus underlies diverse human practices.

Those people and organizations engaged in a practice will understandably often seek to advance it, frequently out of perceived necessity, providing ongoing motivation for improving upon its associated family of routines. That humans seek to advance their practices and that this drives change in technology as routine capability is a core assumption of our perspective.

Institutionally interpreted, it is understood that a human practice takes place across social units, for example, across manufacturing firms or universities. Some will be leaders in the adoption of a new technology, while others will be followers. Leaders must typically work out many of the problems with a new technology on their own, or with a partner. Followers may benefit from the community that forms to promote the diffusion of the technology (Wang and Ramiller 2009).

An Overarching Perspective

Practice theory is further much concerned with social orders. How prevailing orders shape practices, enable or constrain them, and are often reinforced by them, is a common theme in the literature (classics include Bourdieu (1972) and Giddens (1984)). Schatzki offers instead the thesis that social practices are the contexture in which social orders are themselves constructed (p. 89). For Schatzki, practices are primary in bringing about *social worlds* that come to exist:

> In sum, social orders are largely established in practices. The relations among, meanings of, and, hence, positions of, the components of social orders are beholden, above all, to the doings and sayings that compose practices, in conjunction with practice organizations. The arrangements of people, artifacts, organisms, and things that help form the site of the social are laid down primarily in the inter-

[10]Feldman et al. (2016) observe that several papers in their collection examine the relationality of routines, suggesting that future work "move beyond organizational routines as the unit of analysis and consider relations among routines and networks of routines" (p. 511). A new focus on materiality is also suggested. Our own perspective, centered on human practices constituted from device-enabled routines, provides a framework for pursuing future studies along these lines.

> weaving and inter-related nexuses of activity that entities of the first of these sorts carry out (p. 101).

Schatzki thus also gives primacy to human agency.

Elaborating on social worlds by illustration, Schatzki characterizes day trading on the NASDAQ as a "practice-order bundle" or complex and the overall day trading industry as a "confederation of nets of practice-order bundles" (p. 169). Further, and importantly, day trading itself is seen to *cohere* with the practice-order complex of day trading firms that provide for it, while it *competitively intersects* with the practice-order complex of professional market making. The different practices and their routines are intricately interwoven. For instance, even within a single day trading firm, a range of practices, associated with marketing, law, planning, accounting, technical operations, education, and support, are carried out through interlocking routines. In the case of the professional market making complex, it provides the competitive opportunity niche and the context for day trading through the price spreads with which it works. Its own routines are aimed in part at thwarting the exploitation of spreads by the day trading industry, which can drain its profits. The broader point in this case illustration is that practice-order worlds are constituted by both cohering and competing practices. The advancement of any one practice takes place in such settings.

We can summarize now by means of an overarching perspective in which technology as routine capability finds its place. We will say that technology manifests itself in four constitutive and contextual spheres—those of worlds, practices, routines, and devices—as portrayed in Figure 1, in which the nesting of the spheres indicates the relatedness. Note that the various worlds in which we live and work are shown as substantially constituted from our human practices and as providing the context for their advancement. Practices are shown as constituted largely from families of routines that provide capabilities. Routines are themselves purposed and developed in this context. Indeed, following Schatzki, *routines presuppose practices* (p. 96). Routines and their actions are substantially constituted from devices that provide them with affordances. Human and machine actors are also engaged (else no actions). Devices not embedded in other devices provide affordances only in the context of routines.

From our new perspective, it is straightforward now to see how devices are necessarily fused with routines in the larger scheme of things. As already said, when we speak of technology as routine capability, we mean to bring routines to the forefront of the interpretation. From Figure 1, all four spheres are necessary to our understanding, which, in short, is that devices provide needed affordances, not alone, but as incorporated in routines, which provide needed capabilities, not alone, but as incorporated in practices, which advance or not in their respective worlds. When we would say, then, that a world of manufacturing, or medicine, or education, or government, is increasingly saturated with IT, we would mean that its advanced practices are increasingly composed of routines that themselves increasingly incorporate IT devices. Which sounds simple enough, but is also to say that in the absence of routines, our understanding of IT and its devices would be at its core empty. It is routines that through their purposed actions give life to IT.

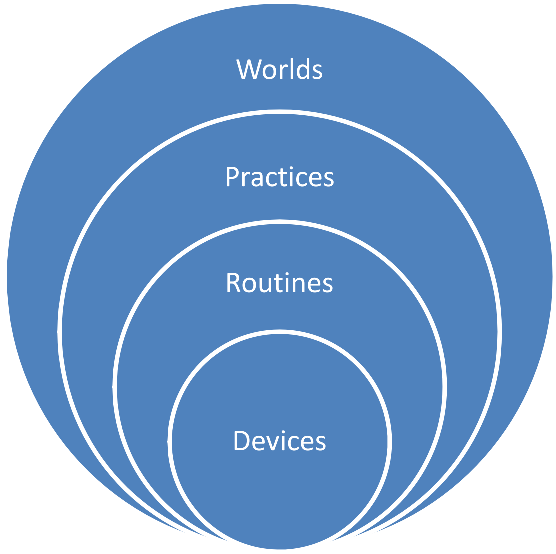
ERP Technology as Routine Capability

It will be helpful to examine the four spheres of technology in the case of ERP (see Pollock and Williams 2009; Shanks et al. 2003). Following the explanatory key of Figure 1, we note first the world in which ERP originated in the 1990s, that of manufacturing, constituted from practices including manufacturing engineering, plant management, operations management, quality assurance, purchasing, human resource management, and accounting, all characterized by advancements in routine capabilities since their origins. In particular, the rationalization of operations through industrial engineering since the 1910s set the stage for IT applications that came to include material requirements planning (MRP) in the 1960s and manufacturing resource planning (MRP II) in the 1980s, providing new capabilities in routines afforded through the software. ERP as conceived aimed to build from this to coordinate operations management, accounting, and human resource management. Among the new routine capabilities sought, for instance, were those that better informed worker assignment and training to meet the changing needs of operations.

With ERP, these routine capabilities were sought largely through the device of packaged software marketed by vendors such as SAP and Oracle. As noted by Kallinikos (2004, p. 2),

> Enterprise Resource Planning packages represent a powerful means for segmenting, organizing and carrying out work in organizations. They establish distinctions and work items throughout the organization, connect them within and across functions, bring about standardization in input and output data and set up elaborate procedures to be followed with respect to the execution of organizational tasks.

Volkoff et al. (2007) suggest that organizational routines are essentially "embedded" in the ERP software; however, we would prefer to say that the device sphere substantially interpenetrates and anchors that of the routines that will come to



Explanatory Key: Technology manifests itself in four constitutive spheres: those of worlds, practices, routines, and devices. The nesting of the spheres portrays their relatedness. From the outside in, first, the various worlds in which we live and work are substantially constituted from our human practices. At the same time, these worlds provide the contexts for the advancement of practices. Second, similarly, our various practices are constituted largely from families of routines that provide capabilities. Routines are themselves developed in the context of human practices. Third, routines are substantially constituted from devices that provide affordances. Devices not embedded in other devices provide affordances only in the context of routines.

Figure 1. Four Spheres of Technology

envelop it. Either way, ERP as routine capability constitutes a forceful "technology of action" (Kallinikos 2004), aimed at coordinating functional practices.

Of course, for any adopter, ERP's routine capabilities are not provided merely by the device of its software, however elaborate the incorporated business rules. Rather, they are built in the development and execution of the routines employing the software, in social as well as human–computer interaction (HCI) where the actions of users and the machine interlock. While this HCI may be highly structured by the software, the affordance provided must essentially be constructed by routines as part of building capabilities across functional practices. In this interpretation of affordances as "action potential" (Majchrzak et al. 2016), then, the potential is not fixed a priori between actor and device, but rather is itself developed in building routine capabilities. Nothing has more "action potential" than a well-afforded routine, it might be said. Too, each new capability achieved opens the door to other creative use and furthers new action potential.[11]

[11]This view is essentially consonant with Leonardi's (2013) argument that "affordances and constraints are *constructed* in the space between social and material agencies" (p. 70, emphasis added).

As it turned out, with ERP, the learning required to achieve routine capabilities would prove to be exceedingly painful for many organizations, who moved *en masse* to adopt it in advance of the new millennium (Robey et al. 2002). Significant problems arose in use, not just in implementation. Boudreau and Robey (2005) provide a post-implementation study of one state agency's experience, where users were initially overwhelmed by the system and at first resisted it, but eventually came to build their own routines for working with it, gaining affordances beyond those that might have been imagined by designers, while leaving other system aspects unexplored. Thus, even with ERP, or maybe especially with ERP, building routine capabilities is an effortful accomplishment on the part of users, as routine theory would suggest. We elaborate further on this story below.

Summarizing thus far, from our overarching perspective, and from its fundamental assumption that humans seek to *advance* their practices, we should also gain new insight into technological change. Following Arthur, any theory of technology is interesting to the extent that it helps account for such change. From Figure 1, we see that change in routines likely arises in conjunction with change in the devices that afford them as well as with change in the practices that draw upon them. Change originating in any of the spheres is likely to entail change in the related others. When we ask what changes IT such as ERP, then, we need to keep the whole of this in mind.

What Changes Technology as Routine Capability?

Following Schatzki, we argue that technology develops largely as means to advance human practices. This provides for a rather different interpretation than offered by Arthur, who ties technological change to economic development. Through a practice perspective that brings routines to the foreground, we can address social change both within the economic system and elsewhere.

We address change in technology as routine capability by considering four principal *modes* of change in advancing practices: (1) *design*, in creating new devices and routines; (2) *execution*, in operating devices and performing routines; (3) *diffusion*, in spreading devices and routines to a population's members; and (4) *shift*, in adapting devices and routines to change among a world's practices. We show that these modes of change play out rather differently for devices and routines, with ramifications for their fusion in achieving new capabilities. At the same time, change via the four modes is interrelated and change by one mode is often associated with concurrent change by another. Advancing a practice also typically engages distinctive practices dedicated to change itself. In the end, our change perspective will be an ecological one, paralleling, but different from the evolutionary one of Arthur.[12]

Change by Design

Much change in technology as routine capability occurs by design, through creative activities inspired by ideas as to how to advance a practice, applied not only to devices, but directly to routines themselves. In the IT context, a good example is business process reengineering (BPR) in the early 1990s, which focused on efficiencies attainable through better engineered routines (Hammer and Champy 1993). The particular IT needed was determined in BPR from the new routine, in contrast to the ERP movement that followed, where adoption of purchased ERP software drove the choice of routines needed to employ it (Davenport 2000). Here, the amused reader may be reminded of the question as to which comes first in new technology, the tool or the routine, which we now see is not an idle one and has practical ramifications, as one or the other may be given design precedence with great consequence.

With ERP, change by design over the years has essentially been a complex shared activity, undertaken by vendors of packaged software "solutions" working with customers of varying needs.[13] Software designed to serve many is leased and "tailored" to the adopting enterprise through the complicated choice of modules configured to meet local needs (Robey et al. 2002). Notably, the amount of tailoring undertaken has changed over time. While early ERP adopters often undertook extensive tailoring at significant cost, later adopters tended to opt for "plain vanilla" off-the-shelf solutions and reworked their local routines to reflect the "best practices" of those who went before them. In the meantime, vendors learned extensively from customer adoptions and incorporated new functionalities in ongoing product development, to further the technology's diffusion (Pollock and Williams 2009).

More generally, in traditional design approaches, changes in both devices and routines are undertaken through normal systems engineering, a practice well described by Arthur. However, the design challenges faced are rather different for devices and routines. With devices, a new or modified one must typically be *specified, built*, and *tested*. Designers, such as software engineers, can usually draw upon development methods well established in their own professional practice. Their routines are distinct from and may or may not cohere well with those of users of the devices. With IS, this often comes to light in struggles between designers and users to specify and agree to requirements, a classic and enduring problem of the field.

Where systems engineering does confront the design of routines, it faces the challenge that they cannot really be specified and built as can devices. With human routines, such 'building" may be possible only in their ostensive aspects, where associated procedures may be articulated and documented, in a form of *composition*. While *instruction* in procedures may also be given, the routines themselves remain "dead" until brought to life in *performance*, as described by Pentland and Feldman (2008). Too, the notion that prescribed procedures will (or even always should) be followed by human actors performing engineered routines has always been

[12]More than one reader of this paper has noted the relevance of certain complexity theory to our interpretation. See, for example, Page (2010), who provides models for understanding diversity and mechanisms of change in a variety of evolutionary and ecological contexts. Exploring such models in the context of our own perspective is left to future work.

[13]Pollock et al. (2007) provide an excellent examination of how ERP undergoes shared design. Initially a vendor works closely with a customer to develop a module, which can then be marketed to others. Some customers become strategic to further development, while others do not. As the market scales, user groups are formed to give collective voice to concerns and needs.

a shaky proposition. Thus, in routine performance, written procedures as a design product tend to become just another device, consulted or not as needed, and subject to becoming quickly outdated, as users learn by adapting their actions to the circumstances faced.

The hallmark of change by design, then, is the completion of an orderly *design cycle* (Pentland and Jung 2016). With modern devices, change is *engineered*, involving not only specification, build, and test, but controlled release.[14] Additionally, once procured and put into use in whatever quantity and circumstances, devices will need to be *maintained*, which in the case of software, requires additional design cycles and a specialized support structure.[15]

With routines, however, the design cycle cannot be so crisp, and requires a different support system. However composed, and however widespread the intended use, routines remain essentially unrealized upon arrival as a design product. They must ultimately be performed locally, bringing users and site-specific circumstances into the picture. Thus, especially with organizational IT, such as ERP, change by design of routines also typically requires a substantial period of *implementation*, entailing user training, often lots of it. As learning ramps up, unforeseen problems also arise, requiring routine adaptation, in which users often take the lead, sometimes without re-engaging the design cycle. Designers may or may not learn of this. Once performances begin, local variation in routines is also introduced, as what is learned by users building capabilities across locations will differ (Yamauchi and Swanson 2010). Such variation can compound the challenge of engaging in another design cycle, requiring another round of implementation. All this requires time with the consequence that change by design can be slow and lumpy, even with maintenance subsequent to initial implementation.

Change by design, for both devices and routines, thus takes place through multiple practices which support it, which require their own technologies and expertise. System engineering in particular is a practice often quite differentiated from those supported by the systems themselves. Still, following Schatzki, any design practice desirably coheres with its supported practices. Advances in system engineering practice are often aimed at facilitating the change process in implementation, as with the development of newer "agile methods," which aim to shorten and speed the cycle by delivering solutions more quickly in smaller increments.

Importantly, whether designed or not, once performances begin, even as "dress rehearsals," routines will originate and coalesce rather quickly around the introduction of new devices (Tyre and Orlikowski 1994). Where there are problems, there may be little or no time to solve them through the design cycle. Routine capabilities must often be achieved in routine execution, on the spot.

Change by Execution

More broadly, then, in the advancement of practices, routine capabilities are necessarily built over time through repeated local routine execution. A technology that entails demonstrable "know how" cannot be delivered by design or by new devices alone. The necessary learning requires *doing*, here termed execution, as has long been recognized (Arrow 1962; Levitt and March 1988; Nelson and Winter 1982). Importantly, this learning through repeated execution is not itself as routine as the term commonly suggests.

As already discussed, routines are not fixed, but rather adapted to the situations faced and the problems that arise (Feldman and Pentland 2003). Every performance presents an occasion for adaptation, through discovering a new device affordance, or appropriating a new device, for instance, or introducing new interactions among users and machines, or even with a quick fix to software driving such interaction, or with a workaround when necessary. In short, learning through repeated execution entails substantial ongoing *improvisation*. With each new problem encountered and solved, routine capabilities grow in turn, beyond those anticipated in design and implementation.

Of course, what is learned in routine execution may also initiate another design cycle, in particular for the devices, as in the need to update software with more than a quick fix. As research has shown, application software maintenance consists substantially of providing enhancements beyond simple fixes. The software itself tends to grow and elaborate over time with new functionality, becoming more complex (Lientz and Swanson 1980). While further complicating maintenance, this nevertheless contributes to increased routine capabilities.

[14]With devices brought to market, change also involves preparations for production and distribution. As production ramps up in the case of traditional manufactured devices, the classical learning curve is encountered, and problems in achieving yields may need to be resolved with design modifications. With software, the problem of achieving production yields does not apply as such, and, moreover, it can be distributed without traditional logistics, speeding the process of delivering a design product.

[15]With traditional manufactured products, maintenance also requires a significant after-sales service operation, physically distributed as needed. Broadly, we observe that the design cycle for engineered devices of all kinds is supported by an elaborate system of specialized practices.

In change by execution, then, devices may be operated in new ways and must also be maintained, while the routines that employ them are adapted through improvisation in repeated performances to achieve greater capabilities. The change mechanisms would thus appear to be rather different for devices and routines. However, Pentland and Jung (2014) posit that routines change through a recombination process in repeated execution, following Arthur, who posits that devices are changed through recombination in the design cycle. While the change mechanisms associated with devices and routines may be different, they may thus introduce novelty in a similar way.

The building of routine capability through repeated performances is more likely to be associated with gradual, incremental change, than with radical change. Still, change through repeated performances can be subtle, complex, and far-reaching. Routines are not typically performed alone, as part of an isolated practice, but rather in concert with other interlocking routines associated with multiple, interwoven practices, as Schatzki would remind us. Even within a single firm, the use of ERP is coordinated across multiple functions and their practices, often operating in separate "silos" as seen by an often frustrated management. Wagner et al. (2010) provide an illuminating case where practices failed to cohere as envisioned, and a temporary patch became permanent. Berente et al. (2016) provides an in-depth study of NASA's ERP system, where routines evolved to serve as useful "shock absorbers" between management and the practices it sought to control. As illustrated in particular with ERP, the coordination of interlocking routines through repeated performances across multiple practices is a substantial accomplishment.

Interestingly, where IT is involved, the devices associated with routines can sometimes be maintained even during routine performance, between related routines for instance. A good example is the automatic update of Windows software between use sessions. Physical changes to devices during their operation are more likely to be problematic. Still, parts may sometimes be quickly swapped, as with battery replacement. More generally, of course, users have tinkered with their tools in working with them, since tools were first devised (Wynn and Coolidge 2009). Users have always sought greater affordances from their devices. Even with ERP software that cannot be changed on the fly, users may tinker with functionality to gain new needed affordance. Tinkering is thus an important aspect of building routine capability.

We note that technology as routine capability may change even without changes to the material devices themselves. For instance, a device employed in one routine may be repurposed for use in another. Pentland and Jung nicely describe how cell phones came to be used in positioning routines, where mobile users could coordinate where and when they would meet. Where devices are thus flexible in their use, new routine capabilities may be achieved entirely by their users.[16]

Change by Diffusion

Advancing a practice entails much more than building routine capabilities through repeated local performances, however. Eventually, for the practice as a whole, the learning must be global to the population, accomplished through change by diffusion (Rogers 1995). Sometimes viewed as a form of social contagion, the diffusion of technology is seen more closely to engage a highly purposeful set of activities, as in technology transfer, in economic development, where it is well understood that the knowledge needed to produce and use some new device cannot be "moved" as can the device itself (Bozeman 2000). In our terms, such knowledge as capability is inherently local to practices and the execution of routines that constitute them. Which is not to say that it cannot with effort be substantially replicated elsewhere.

Here we are interested primarily in technology diffusion in the absence of managed replication, where adoption decisions are made one by one, but with multiple institutional players, such as industry and professional associations, actively engaged in promoting the change for all.[17] With certain IT, this involves the promulgation of an organizing vision that explains what the technology is and why it should be adopted (Swanson and Ramiller 1997). Whether the technology diffuses widely or not may hinge on the successful launch of the vision (Wang and Swanson 2007). Where the vision lacks coherency, diffusion is problematic (Currie 2004).

While new technology as routine capability is always a local accomplishment, even as it diffuses, each new adoption offers a new occasion for *community learning*, as described by Wang and Ramiller (2009). The underlying diffusion mechanism is one of adaptive *imitation*, where what is learned with each new adoption feeds back within the community to motivate further change by design and execution.

[16]Of course, this may also spark redesign of the device to capitalize on these new capabilities, as illustrated by the emergence of the smart phone from the ordinary cell phone, with Web access and apps now offering mobile users a wide array of location-based services (Rao and Minakakis 2003).

[17]The engagement of institutional players takes the form of institutional entrepreneurship (Hardy and McGuire 2017). In our terms, this involves institutional work among different practices (Lawrence et al. 2010), where agency "is something often accomplished through the coordinated and uncoordinated efforts of a potentially large number of actors" (p. 55).

Again, ERP, a technology envisioned and promoted by the industry analyst firm Gartner, provides a useful illustration. Originally conceived for the manufacturing industry, ERP came to diffuse rapidly across larger firms in multiple industries at the turn of the millennium. Ostensibly, the benefits to be obtained were to come from better coordination across the firm's practices, although the "know why" associated with adoption proved to be a changing story (Wang and Ramiller 2009), discussed further below. Consultants facilitated the vast implementation process, often using "templates," drawn from prior engagements, to aid in introducing the necessary new routines, reducing tailoring costs among parties associated with the effort (Pollock and William 2009), while also leading to routine normalization. At the same time, learning from each adoption, ERP software providers adapted their products to incorporate additional needed functionalities.

In change by diffusion, then, the challenge for device makers is to *distribute and extend* their wares to the broader population, adapting them as needed. The opportunity is to capture a significant share of the new and growing market, as SAP did with its R/3 product. Each competing provider trumpets the features of its own product or service, as well as the compelling advantages of the new technology, typically articulated in terms of capabilities that the devices purportedly bring. With digital goods, competing vendors are further challenged, as adaptive diffusion may also be sped through open source offerings that free the adopter from reliance on any one of them.

For the adopter, the advantages come not from the devices alone, but from the routine capabilities they must themselves achieve. The majority is most likely to commit to the technology, where the evidence is that those who have already done so have been successful, such that broader practices are being changed, and one cannot afford to be left behind. They seek to learn from others and *replicate* successful routines and experiences. Wang and Ramiller (2009) describe how adopters of ERP came to communicate their implementation experiences and lessons learned to others in the trade literature of the time.

Apart from such imitative change, change in technology as routine capability may also arise through conscious effort to advance a practice in a new way. Radical change may be sought globally among many social units all at once. Historical examples in the financial industry include the establishment of bank ATMs and their networks (McAndrews 1991). In the health care industry, an example is the establishment of insurance exchanges, both state and federal, under the U.S. Affordable Care Act. Massive changes in routine capability are characteristic in each of these illustrative cases. Predictably, such change is not actually achieved everywhere all at once.

We note that change may occur more swiftly where adopters are independent, achieve routine capability relatively easily, and where network effects are supportive, as with the individual adoption and diffusion of Twitter. Change among organizations is in general a more challenging proposition. Adoption requires an organizational rationale, routine capability must be collectively achieved, and network effects may or may not be in play. It typically proceeds less swiftly, notwithstanding early experimentation with new devices promising new rewards.

However swift the change, where routines are concerned an important aspect is their *normalization* and institutionalization. The greater the social sweep of adoption, the more likely the routines, if not the full capabilities, will eventually be roughly common across players, even with continued local improvisation and adaptation. So-called "best practice" comes to be expected and is continually reinforced. And so practice is changed with new technology for the many, not just the few.

Change by Shift

Changed practices are not permanent, however. Following Schatzki, the large variety of human practices and their associated routine capabilities coexist in an ecology of sorts, in which they both cohere and compete with each other for our time and efforts. As is well known, not all practices persist endlessly or with the same frequency or intensity, or even in the same locations. While new ones originate and flourish, as with financial engineering, web design, and blogging, for instance, others wither and recede, as with stenography and professional typing, or morph into something else, as with typesetting and bookkeeping, or fall away altogether, as with telephone switchboard operation. So too do associated routines and capabilities, as performances increase, or diminish, or even cease. All this also takes place at varying paces around the world. We refer to this process of practice ebbs and flows, contractions and expansions, and the emergence and development of new practice mixes, as change by *shift*.

In economics, the kind of shift we are talking about is often discussed as change marked by innovation, entrepreneurship, and "creative destruction," dating to the work of Schumpeter (1912). Much of this work focuses on change and upheavals among industries and the fortunes of firms and their products and services. More recent work in evolutionary economics emphasizes the importance of knowledge and skills in achieving firm performance. Useful knowledge and skills are seen as unevenly distributed in the economy. Too, the profit motive stimulates this through continuous search for better goods and services and means of production. Useful knowledge and technology are "restless," and "there are always good reasons to know differently" (Metcalfe 2010, p. 160). As a consequence, where technology is concerned, the economy can't be considered a system in equilibrium, as it is in neoclassical theory. Rather, it must be seen as dynamic, in flux, and as an ongoing problem-generating and problem-solving structure. It gives rise to what Arthur refers to as *opportunity niches* in motivating the development of new technology. Such niches are closely associated with shifts in practices.

With devices, opportunity may give rise to a "disruptive" innovation that, through redomaining or reinvention, undercuts a dominant product's economic position (Bower and Christensen 1995), resulting in a practice shift. In the case of ERP, SAP's R/3 product, which moved a mainframe-based product to one employing newer client/server and relational database technologies, proved highly disruptive (Pollock and Williams 2009). Research suggests that the rapid move to ERP was motivated in part by a corresponding shift in computing practices, away from mainframes, toward client/server architectures, quite apart from the vision as to how manufacturing practices would be advanced.[18] It suggests too that an additional motivation was the desire to replace homegrown legacy software susceptible to the Y2K bug with new packaged software, setting in motion another practice shift that cohered with achieving better control over IT, if not manufacturing. Most recently, still another shift in computing practices, toward offering ERP software as a service, has presented vendors with yet another opportunity to attract and retain customers, in particular those wishing to forgo in-house computing altogether.

Again, opportunity niches exist not only for the introduction of new devices. They exist for the development of new routine capabilities. Socially, in our human practices, we are as restless for new ways, as we are for new devices. Both motivate the development of new technology. Davenport (2000, p. 7) described how management imagined its own practice might be transformed with enterprise systems:

> In an ideal world, ES-enabled organizations would be seamlessly connected both internally and externally. Excess inventory and waste would be nonexistent. Demand and supply would be perfectly coordinated. It would be just as easy to transact business with suppliers and customers as with another department of your own company. Customers would have perfect information about not only the products and services they've ordered from you, but about how every aspect of your business affects theirs. Managers could understand any aspect of a company's operations and performance with a few clicks of the mouse.

In something of an irony, then, the widespread adoption and ongoing adaptation of ERP is seen to have been driven in part by shifts in practices both real, in the case of computing practices, and perhaps over-imagined, in the case of management practices. Which is not to say that firms have not eventually found ways to achieve new routine capabilities with ERP.

Of course, routine capabilities are important not only to firms and their managers. They are important to people that help build them and engage in them and to society more broadly. Change by shift implies change in occupations, for instance, along the lines of our examples above. It also has broader social ramifications. A current example exists in journalism, where with the decline of the print newspaper business, fewer professional journalists are employed, with the consequence that less journalism altogether may result, with negative consequences for an informed public. Still another example exists in higher education, where with MOOCs (massive open online courses), it is said that instructional efficiencies may lead to consolidation in this sector, with fewer opportunities for college teachers, and homogenized education for students, with less learning by traditional face-to-face contact. Following Schatzki, the tensions in both these prospective shifts might be illuminated by a focus on the routine capabilities being built among competing and cohering practices. In change by shift in practice, the broad challenge is to adapt and recreate.

Of further importance in this change, one shift likely implies another, in the ecological context. The process is ongoing, path-dependent, and without equilibrium. Restlessness ensures that routine capabilities will be in continuous flux and adjustment, in the advancement of human practices. In sum, while technologies as routine capabilities change by design, execution, and diffusion, they prosper and persist or not through shifts in associated human practices. Schatzki, in his careful description of the origins and rise of day trading on the NASDAQ, provides an excellent case example (pp. 157-174). From its origins as a computerized market in 1971, Schatzki describes a series of NASDAQ reforms giving individual investors greater access and better associated infor-

[18]Hirt and Swanson (1999) describe one firm's move to adopt SAP R/3, driven substantially by its desire to replace its expensive mainframe system. Wang and Ramiller (2009) examine the varying "know why" for ERP adoption.

Table 2. Technology Change in Practices, Devices and Routines

Practice Change Mode	Devices	Routines
Design Advance a practice by developing devices and routines to achieve new capabilities	**Build and test** Example: develop new enterprise software requiring new organizational routines	**Compose and instruct** Example: develop new organizational routines for using new enterprise software
Execution Advance a practice by building new capabilities in carrying it out	**Operate and maintain** Example: provide fixes and new functionality to enterprise software as necessitated or requested in its use	**Perform and improvise** Example: discover new enterprise software affordances in its use, or work around the lack of such affordances
Diffusion Advance a practice by diffusing new capabilities to new adopters as best practice	**Distribute and extend** Example: market enterprise software to additional adopters and provide new versions to meet their needs	**Replicate and normalize** Example: employ consultancies to help implement purchased enterprise software following best practices
Shift Advance a practice by adapting capabilities to shifts among other practices	**Redomain and reinvent** Example: reconceive and redevelop enterprise software as a service and offer it in the cloud	**Adapt and recreate** Example: develop new support routines for using enterprise software provided as a service

Explanatory Note: Technology change in advancing practices occurs through four interacting change modes: design, execution, diffusion, and shift. Change by each mode takes distinctive forms for devices and routines with implications for their fusion in achieving new capabilities. Change by one mode in advancing a practice is often associated with related concurrent change by another. Change in worlds (not shown) is achieved through changes in practices.

mation, spawning day trading, which both competes with established market making and coheres through day trading firms in the broader NASDAQ scheme of things. Only through an understanding of shifts among related practices, are we able to grasp the significance and value of the associated routine capabilities and, thereby, the technology itself.

We summarize this section's discussion in Table 2, which compares forms of practice change across the four modes of design, execution, diffusion, and shift. It is seen that forms differ for devices and routines, even as they join together to provide new routine capabilities. As we have also emphasized, from a routines capability perspective, neither devices nor routines comes necessarily before the other. Learning is necessary across the four modes for both devices and routines.

Change may be initiated in any of the shown forms. This offers a rather different interpretation of change in technology than would be suggested by a traditional device perspective. The need to grasp technology as something more than devices is highlighted. So too is larger scale technological change in practices beyond smaller scale change in the routines that comprise them.

Discussion

Revisiting the question with which we began this essay, what comes first then in technology, the device or the routine? While the everyday understanding and related design literature (e.g., Norman 1990) suggests, for the most part, that it is the device, to the neglect of the routine, we have sought here not so much to reverse the order, as to bring routines to the foreground of the story. We have argued that changes in routines can lead changes in technology, as much as can changes in devices. Changes in each anticipate changes in the other.

We have sought here to elaborate on the technology story offered by Arthur, which focuses primarily on devices and gives prominence to their engineering, more than to their use. While the notion of routines is perhaps latent in Arthur's work, we believe that it deserves to be brought forward and have sought to do so. Consistent with the important work of Pentland (2015), Pentland and Feldman (2008), and Leonardi (2011), we have retained a conceptual distinction between routines and devices, but taken a further step, joining both within a broader view of technology that goes beyond a device-centered perspective and yields new insights.

Relying on Schatzki's practice theory, we have developed an overarching perspective that incorporates devices with routines, routines with practices, and practices with worlds. In our elaborated technology story, the affordances of devices are seen as manifested in routines, while the capabilities of routines are manifested in human practices, which thrive or not in their respective worlds. Change in technology is given an ecological interpretation centered in advancing human practices, rather different from Arthur's evolutionary interpretation centered in advancing devices, but not incompatible. While Arthur's view provides deep insights into the engineering of new devices, our own view suggests that important insights come as well from studying how routine capabilities that employ our various devices actually come to be achieved.

When we observe that our larger global world seems saturated with devices then, our overarching perspective explains why. Technology is only served by its devices. It is delivered in the form of routine capabilities. These in turn are constitutive of our human practices, which we seek to advance. When we look about at all our devices, we need only ask, "What are we trying to do here?"

While technology is our focus, we note that our overarching perspective also speaks to those interested primarily in routines. Parmigiani and Howard-Grenville (2011), in a recent review, contrast research on routines from the capabilities and practice perspectives, observing that "researchers in each group seem to be having parallel conversations" that do not speak to each other (p. 414). They suggest that scholars address how these two perspectives interconnect. Curiously, much of the reviewed research on routines seems little concerned with technology, however.

D'Adderio (2011), in her helpful review of routine theory calls for bringing artifacts to the center of routines and suggests several steps for doing so. She identifies software and information systems, in particular, as important to theorize in these terms. Nevertheless, in accommodating artifacts, she anchors her suggestions firmly in existing routine theory, rather than in a larger technology story in which routines are themselves anchored, as in our own perspective. Similarly, Pentland (2015), in his new work, positions technology as artifacts within routine theory, elaborating on the narrative network model (Pentland and Feldman 2007).

Extending Parmigiani's and Howard-Grenville's pointed comparison of the two traditional perspectives, our own perspective on technology as routine capability provides a fresh view of routines as shown in Table 3, with interest centered on how routines fuse with devices in practices. As can be seen, the focus on practices as constituted from routines enables the pursuit of important research questions that simply do not fall within the scope of traditional perspectives. In particular, the behavioral assumption that humans seek to advance their practices serves to motivate studies that would examine how all this works out with new technologies in a changing world in which any practice both coheres and competes with others.

Our examination of technological change in devices versus that in routines offers additional insights. Four modes of change—design, execution, diffusion, and shift—are identified and provide for an integrative view. In the case of change by design, we have pointed out the problems associated with applying the design cycle to routines, as compared to devices. As routines are fully realized only in their performance, their design might be said to be incomplete, pending execution (Carroll 2004). In the case of change by execution we have described how routines can be altered with each performance, while devices are typically less adaptable, though more so where they are digital. Learning by doing is largely local to a routine's performance, however, presenting challenges to adoption of the technology more widely. In the case of change by diffusion, we have argued that adoption of devices must be differentiated from the collective building of a population's routine capabilities, which requires community learning through an infrastructure of supporting practices. Whatever routine capabilities are achieved, they and their devices remain vulnerable to shifts in associated practices, however. In the case of change by shift, we have suggested that ecological shifts among practices and their routines follow from a restlessness similar to that described by Arthur for an evolutionary economy and devices offered in the marketplace. Following Schatzki and our behavioral assumption, we argue that the advancement of practices is primary in the overall story of technological change.[19]

The four change modes are of course linked with each other. Change by design is interwoven with change by execution much as described by Leonardi (2011), who applies the notion of imbrication to human and material agencies. Both are intertwined with change by diffusion, as capabilities accumulate more broadly to a population. Change by shift provides ongoing impetus to the process, opening and closing opportunity niches for advancing human practices. Change by all modes is ongoing and stability is a temporary phenomenon. Creative restlessness prevails and there is no equilibrium.

Broadly, a *new technology*, then, is a capability forged from introducing new devices and routines to a human population and its practices. The notion that a technology is *forged* is the idea that it is brought into being and given its shape by a community of actors, including the providers of new devices, the builders of new routines, and a host of other players and promoters, who bring institutional infrastructure in support of the technology's diffusion. A closer focus on these actors' collective practices might enable us to better understand the bridging activities that bring new technology to widespread use (Leonardi and Barley 2008).

[19]While some readers might thus interpret our view as a return to simple social construction, we would argue otherwise. While seeking to advance practices provides impetus, the building of routine capabilities is a thoroughly uncertain and undetermined process engaging the social with the material. We have sought to build better theory along the lines suggested in Leonardi and Barley (2008).

Table 3. Perspectives on Routines: Extending Parmigiani and Howard-Grenville (2011)

	Traditional Capabilities Perspective	Traditional Practice Perspective	Technology as Routine Capability Perspective
Main interest	What routines do and how they lead to firm performance	How routines operate, internal dynamics	How routines fuse with devices in practices
Focal level of analysis	Firms	Routine itself	Practices as constituted from routines
Unit of analysis	Routines as "entities" (whole routines)	Routines as "parts" (internal structure)	Routines as both "wholes" and "parts" in practices
Research attention	• Firm-specificity of routines • How routines create value and lead to differential performance • How routines build to form capabilities • Complementarities between routines • Transferability within and between firms	• Actors' influence on routine performance • Artifacts' influence on routine performance • How routines change and remain stable over time • How routines are created or changed • When and how routines break down	• How new devices lead to new routines and vice versa • How new devices fuse with new routines • How routine capabilities develop and diffuse • How practices are advanced by routine capabilities • How practices grow and contract with new technologies
Behavioral assumptions	• Bounded rationality • Organization-specific foresight • Potential self-interest • Agents act as expected	• Human action is effortful • Everyday activity constitutes social life • Agents are not replaceable	• Humans seek to advance their practices
Stability and change	• Acknowledge change, but more interested in stability	• Change and stability always possible • Same mechanisms underlie change or stability	• Change is ongoing and stability is a temporary phenomenon

In summary, our view of technology as routine capability offers a new perspective from which to conduct future research on technology and how it underpins most of what we do, as well as where we are presently going with it. It provides a coherent theoretical lens that ties together previous strands of research and shows how technological change by any one mode is intimately related to change by the others, suggesting that future research should explore these cross-modal changes, in particular. We conclude with several suggestions for this research, where much of what is needed is likely to be case studies, although not always of the traditional kind.

Traditional case research most often addresses contemporary adoption of a single technology in a single organization. Its prevalence no doubt reflects the opportunities that come to the researcher, as well as the abundant interpretive stances that may be taken. Where focused on routine capabilities, it can continue to offer insights. It can be sensitive in particular to individual and organizational *actions*, and how they both constitute routines, and are enabled by them. It can speak to adaptive change through actions, whether by design or in routine performance. Just as important, it can address how routine capabilities are built to link multiple practices within the organization, which while different must cohere in a practice-order world.

But beyond this, we especially encourage research that "zooms out" to address how technology as routine capability is forged in advancing practices beyond the single organization to embrace whole industries and professions. With this in mind, we encourage (1) studies of technologies whose developmental paths are intertwined across multiple practices; (2) studies with a substantial historical dimension; and (3) studies that relate technology change to larger ecological shifts and the transformation of practices in terms of how they compete and cohere.

Boland et al. (2007) provide an exemplary study of the introduction of digital 3-D technologies in Frank Gehry's architectural practice, speaking to all three of these suggestions. From in-depth interviews probing actions over multiple projects, the authors describe how Gehry's embrace of digital 3-D gave rise to multiple "wakes of innovation" in both his own firm and those of his business partners, and, more broadly, precipitated change not only in the practices of architecture, but in those of the related engineering and construction industries.

Studies of multiple technologies over time are necessary to discern path dependencies in the evolution of routine capabilities. In the case of ERP, for instance, it is known that it was conceived as a "next generation" MRP II. However, while there is a literature on each in its own time, we know of no study that has systematically examined how the one came to displace the other. Following Schatzki, such a systematic study might focus in particular on the roles played by cohering and competing practices in the evolutionary transition. Here we have suggested that cohering changes in computing practices, given mention in Wang and Ramiller, may have played a larger role in the ERP story than has come to be widely understood.

A substantial historical dimension is also necessary to guard against inferences drawn only from present and sometimes transitory circumstances. Many of our ERP studies have been very much of the moment, in particular those that documented with little time lag the notorious implementation problems that arose in the late 1990s, when there was much excitement about them. Now that collective routine capabilities have been largely achieved with ERP, it might be fruitful to ascertain more closely what this amounts to, and how it came about over the years. Too, as it has been adapted, how does ERP now mesh with supply chain management and customer relationship management, as envisioned in the concept of ERP II (Swanson 2017)?

Williams and Pollock (2012) also argue for a historical approach, in the building of a "biography" that documents a "history of relationships and sites implicated in the evolution of a specific artifact and a class of artifacts" (p. 13), going beyond single site implementation studies that have dominated the literature. Pollock and Williams (2009) apply this approach specifically to SAP's ERP product. Additional biographies of important IT devices and their development and offering in the marketplace intertwined with their customer and broader social acceptance would do much to further our understanding of technology change by diffusion. Biographies of complex devices such as sensor networks that monitor changes in temperature, traffic, air quality, or movements of people in environments where multiple practices are differentially affected might yield important insights into larger evolutionary change patterns.

Studies that are situated in shifts in practice that give rise to opportunity niches are particularly likely to be revealing of how technology initiatives are purposed and come to fruition or not. In the case of ERP, we have suggested that shifts in computing practices may have been as important to its widespread adoption as were its original touted coordinative features. In another realm, current shifts in U.S. health care and insurance practices suggest that studies of new technology initiatives and outcomes in this domain might be enlightening. The use of IT in health care has a long and troubled history with much remaining to be worked out for the benefit of all. How should we understand this history and what does this tell us about how to move forward?

To conclude, the view of technology as routine capability serving human practices that we seek to advance suggests that we must raise our research sights to new levels, if we are to grasp the "tsunami" of technology now sweeping over us. In the present paper we have sought to reframe our view of technology and point the way ahead with this insight uppermost in mind.

Acknowledgments

This paper has been a long time in the making and many have been helpful to me. I'm grateful in particular to the senior and associate editors and the reviewers for their encouragement and patient attention to the several revisions. A preliminary version of the paper was presented at the annual meeting of the Academy of Management, Anaheim 2016. I'm thankful too for earlier comments and suggestions received from Brian Pentland, Neil Ramiller, Paul Leonardi, Ted Schatzki, and Lynne Markus.

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