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Unpacking the Dynamics of Ecologies of Routines: Mediators and Their Generative Effects in Routine Interactions

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Building on an in-depth ethnographic study at a renowned research laboratory, we show how the interactions of organizational routines can be more or less generative by tracing and analyzing how human and nonhuman actors (actants) connect routines. Adopting a performative perspective, we compare the connecting of such actants and study how they are engaged in routine performances. We relate observed differences in the generativity of routine interactions to whether actants become mediators or intermediaries. Whereas intermediaries merely maintain connections between routines, mediators can modify them when performing routine connections. We identify three generative effects mediators can lead to: (1) the creation of innovative outcomes, (2) the adaptation of existing routine performances, and/or (3) the emergence of new routine performances. Similar to the conception of organizational routines as dynamic and generative systems, we show that the way actants operate through their engagement renders routine interactions and thus ecologies of routines more or less generative.

Keywords: ecologies of routines; routine interactions; generativity; actants; mediators and intermediaries; actor-network theory (ANT); translation
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Introduction

How are organizational routines an engine in innovation? Scholars have described organizational routines as repetitive, collective, and interdependent action patterns omnipresent in the everyday functioning of organizations (Becker 2004, Cyert and March 1963, Nelson and Winter 1982, Parmigiani and Howard-Grenville 2011). Yet, their role for innovation and specifically for innovation-in-the-making is less obvious and rarely studied. Routines have long been held responsible for inertia (Hannan and Freeman 1984) and mindlessness (Ashforth and Fried 1988). Consequently, many existing studies make a clear distinction between routine tasks and creative tasks in explaining an organization's ability to innovate and in identifying specific activities that would help bring new things into being. For example, Adler et al. (1999) point out the importance of a temporal separation of routine and creative tasks for achieving both higher efficiency and flexibility in an automotive plant. Obstfeld (2012, p. 1571) distinguishes between "how organizations get routine things done and how they pursue markedly new things through creative projects."

However, there is no empirical evidence supporting a general incompatibility between routines and innovation (Ohly et al. 2006, Pavitt 2002). On the contrary, already Nelson and Winter (1982) argued that we should study their relationship in more detail and that there exist firm-specific meta-routines or capabilities that support innovation efforts. Examples include standard operating procedures (Becker and Zirpoli 2009), job control (Ohly et al. 2006), technology brokering (Hargadon and Sutton 1997), or the lead user method (von Hippel et al. 1999). These studies enhance our understanding of the role of higher-order concepts for innovation, but they are silent about the underlying organizational routines and their interrelatedness (Parmigiani and Howard-Grenville 2011, Salvato and Rerup 2011). Consequently, they do not provide insights on mechanisms that would lead to generativity in organizations.

The literature on ecologies of routines provides insights on how ordinary micro-activities drive the dynamic evolution of capabilities by decomposing the latter into routines and corresponding action patterns and artifacts. Salvato (2009), for instance, analyzes the evolvement of the routines over time and shows how mindful improvisation enriches the new product development process at an Italian appliance manufacturer. Birnholtz et al. (2007) do not decompose the ecology of routines pertaining to the organization of a summer camp, but they identify internal regeneration processes that lead to its continuous reproduction and evolution. The cited studies have a strong focus on how bundles of routines evolve and change through situative and repetitive enactments and on processes that support the recurrent performance of an ecology of routines. Yet little is known about the internal

dynamics of ecologies of routines (routine interactions) and how this interaction can be more or less generative.

In this paper, we inscribe ourselves in a performative perspective and build on earlier work that opens up the black box of routines by focusing on their mutually constituting parts, namely performative and ostensive aspects (Feldman 2000, 2003; Feldman and Pentland 2003), and on the role artifacts play therein (D'Adderio 2008, 2011, 2014). More in particular, we draw on actor-network theory (Latour 2005; ANT hereafter) to study the generativity of routine interactions and of ecologies of routines in the wider sense. Accordingly, we conceptualize bundles of routines as constituted of practices connected through actants (Schatzki 2011) and consider that "practices can only be studied relationally, and they can only be understood as part of a nexus of connections" (Nicolini 2013, p. 229). We rely on Latour's (2005) distinction of actants in intermediaries (maintaining connections) and mediators (modifying connections) to capture the role these actants play in connecting routines, how their becoming is more or less generative, and what generative effects they can have.

For our study, we conceptualize innovation as a translation process in which new things emerge progressively and require the continuous aggregation of generative connections. Empirically, we draw on data from an ethnographic field study conducted at the Artificial Intelligence Laboratory (AI Lab) of the University of Zurich. Our observations show that the everyday functioning of the AI Lab relies on the performance of an established bundle of routines. Although the research projects are driven by similar routines and routine interactions, their generativity differs markedly, which promotes or hinders the emergence of new things such as robot prototypes, scientific publications, and so forth. By tracing them across and within projects, we demonstrate that how actants are engaged in routine performances impacts whether they become mediators or intermediaries, rendering the routine interaction more or less generative. We identify three generative effects brought about by mediators: (1) the creation of innovative outcomes, (2) the adaption of existing routine performances, and (3) the emergence of new routine performances.

Our paper makes three distinct contributions. First, we add to the understanding of ecologies of routines by demonstrating that the repetitive performance of routines does not only lead to the reproduction and evolution of ecologies (Birnholtz et al. 2007, Salvato 2009), but that the interaction of routines and, thus, the internal dynamics of ecologies are a source of generativity as such. Generativity derives from the performance of routines (Feldman and Pentland 2003) and from their continuous interaction. Second, we contribute to the research on the role of artifacts in routine dynamics and address the need for a "more dynamic characterization of artifacts and their properties" (D'Adderio 2014, p. 1347) by focusing on the effects that actants have in the connecting of routines. Extending D'Adderio's (2011) findings that human and nonhuman actors (actants in our terminology) mediate the interplay between different aspects of routines, we show how actants connect routines in more or less generative ways. Third, we open up the black-boxed entities of higher-order constructs such as meta-routines and capabilities (Salvato and Rerup 2011) and explore their role in innovation processes (Nelson and Winter 1982). This provides new insights on routine interactions as a source of generativity.

Theoretical Background

In their seminal book *An Evolutionary Theory of Economic Change*, Nelson and Winter (1982, pp. 132–134) insist on the need to examine the relationship between organizational routines and innovation to understand the importance of the latter for firm performance. Indeed, they claim that "organizations have well-defined routines for the support and direction of their innovative efforts." Yet it is uncertain and "not knowable in advance" whether the performance of specific routines will eventually lead to innovative outcomes. The emergence of a new technology or a new process can neither be predicted nor evaluated ex ante, which makes innovation a nonlinear and fuzzy process (Garud et al. 1997, Latour 1987).

One promising approach to study the emergence of new things is by conceptualizing innovation as a translation process that unfolds in the making. Callon (1986, p. 224) defines translation as the "mechanism by which the social and natural worlds progressively take form." Latour (1994, p. 31) specifies that translation is potentially achieved through the aggregation of generative connections sparking from the "displacement, drift, invention, mediation, the creation of a link that didn't exist before, [that] . . . modifies two elements or agents." The translational perspective accordingly allows focusing on the "mysterious script" in the middle that characterizes the rough journey between invention and innovation and that eventually brings new things into being (Akrich et al. 2002, p. 188).

Several organizational scholars have recently used a translational approach to capture the generative character and the fragility of sociomaterial processes underlying innovation processes. For example, Nicolini (2010) applied it to study how cardiac telecare was established and guided through uncertain negotiation processes in northern Italy. Harty (2010) used the concept of translation to show the fragility of the implementation process of a new software. Both authors underline that translation requires work and effort to create chains of generative connections for new things to emerge. Building on this emerging stream of research, we are interested in the role ecologies of routines play for innovation-in-the-making and, more in particular, in how generativity is achieved.

Role of Routines in Innovation

Existing studies on the role of organizational routines in innovation processes mainly point toward the existence of

specific heuristics or meta-routines, which may help firms in their efforts to innovate (Nelson and Winter 1982). For example, Peng et al. (2008) report in their study of a manufacturing plant how the innovation capability is a key aspect in the development of new products and processes, and that it consists of a set of interdependent but distinct routines. These findings are in line with earlier research by Hargadon and Sutton (1997) who identified technology brokering as a core process that enabled IDEO, an international design and consulting firm, to systematically create new products and solutions, and by von Hippel et al. (1999) who found evidence that the lead user method of 3M led to a large number of technological breakthroughs.

As Salvato (2009) points out, most scholars who attribute the capacity to innovate to a specific meta-routine or capabilities conceptualize them as aggregated, higher-order entities. However, they provide only limited insights on the underlying routines and how those work. Taking a micro-foundational perspective instead, Becker and Zirpoli (2009) show in their study on the routinization of virtual simulation in experimentation how standard operating procedures in the new product development process create the stability necessary for innovation to occur. Along the same lines, Ohly et al. (2006) illustrate how routinized processes, e.g., job control or supervisor support, can free up cognitive space for innovation efforts. Whereas these micro-foundational studies provide interesting insights regarding the existence of firm-specific processes that stabilize certain parts of innovating capabilities for innovation to take place, little is known about the constituting routines, their interrelatedness, and their role for the emergence of new things (Parmigiani and Howard-Grenville 2011, Salvato and Rerup 2011).

Some insights on the interdependence of routines and their importance for organizational functioning come from studies on ecologies of routines. Birnholtz et al. (2007) study a summer camp and find that a specific ecology of routines reproduces itself year after year. In particular, they show how changing or replacing parts of an ecology of routines is challenging because the constituting routines are interdependent in the sense of an epistatic system (Miner and Mezias 1996). However, changes may happen through the continuous performance of the routines. In his decomposition of the new product development routine at Alessi, Salvato (2009) shows that day-to-day events alter the sequences of established action patterns and create an incremental renewal of the whole process, which potentially allows for innovations to take place.

Whereas existing research on ecologies of routines helps us to understand the reproduction and change of an interdependent set of routines and thereby reconfirms the overall importance of capabilities for innovation efforts, it remains unclear what role routine interactions play for innovation. This leads Salvato (2009, p. 399) to conclude that future studies should look at "the interplay of existing routines and individuals' everyday mindful acts as the unit of analysis." Accordingly, the goal of this paper is to focus on the internal dynamics of ecologies of routines, conceptualizing them as a socio-material assemblage to understand where generativity derives from (Orlikowski and Scott 2008). Specifically, we ask: *How and why can the interaction of routines be more or less generative*?

A Performative Perspective on Routine Interaction

We build upon the theoretical underpinnings of the "routines as practices" research program (Feldman and Orlikowski 2011), which takes a performative perspective in studying routine dynamics (D'Adderio 2008, 2011, 2014; Feldman 2000, 2003). That is, we view routines not as isolated but as socially embedded constructs with internal dynamics that are not easily transferrable from one context to another (Parmigiani and Howard-Grenville 2011). Feldman and Pentland (2003) emphasize the role of agency in routines and locate their dynamic nature in the recursive interaction between ostensive and performative aspects. Whereas the ostensive aspects "embody the abstract idea of the routine," the performative aspects "consist of the actual performance of the routine by specific people, at specific times, in specific places" (Feldman and Pentland 2003, p. 95). Accordingly, routines should be considered as generative systems creating both stability and change (Feldman and Pentland 2008).

Following this performative perspective, we conceptualize ecologies of routines as bundles that consist of practices (i.e., doings and sayings) connected through material arrangements (i.e., actants) and shaped by their continuous performance (Schatzki 2011). To better understand the generative nature of such bundles, one needs to analytically trace the connections between the routines. This allows identifying the role that actants play in creating, maintaining, and modifying routine connections (Nicolini 2013). It is important to remember that ANT does explicitly not privilege human or nonhuman actors and pays attention to their situative agency in the same analytical way (Latour 2005). The question emerging from this theoretical perspective is how actants become generative in the course of action (routine interactions in our case). To address this question, we point to Feldman's (2016) recent call for a process-based interpretation of routines reflecting that actions are constitutive and relational.

To describe the different qualities actants can take on in action, Latour (2005) introduced the distinction between intermediaries and mediators. In connecting routines, intermediaries transport meaning without transforming it. Mediators, on the other hand, transform, translate, and modify meaning. They have the potential to generate new things, because the outcome of their performance is unpredictable. According to Nicolini (2009, p. 1410) actants tie connections together, but mediators "also move them around." D'Adderio (2011) finds that artifacts acting as mediators may take on a participatory role in routines

by influencing their performances. Recently, she added that "enacting the same action sequence through the same set of artifacts and communities could support the emergence of different, and even contrasting, performances" (D'Adderio 2014, p. 1347).

We rely on the distinction between mediators and intermediaries to understand how actants are involved in performing routine connections and to grasp their generative potential that emerges through their situative becoming. Indeed, as we face "constant uncertainty over the intimate nature of entities [actants] —are they behaving as intermediaries or as mediators?" and because an actant "is what is made to act by many others" (Latour 2005, pp. 39–46), one needs to trace actants that connect routines and focus on their engagement in routine performances to understand how new things emerge in organization. Overall, this approach enables us to account for variations in the generative power of actants connecting routines and enhances research on routine interaction and its role in innovation.

Data and Methods

Research Site

We adopt an inductive theory-building approach to study actants and their generative effects in routine interactions. Our findings stem from a three-year ethnography at the University of Zurich's AI Lab. Founded in 1987 by its director, Rolf Pfeifer, the AI Lab has transformed from a small team with two Ph.D. students to a globally networked organization that employs people from such diverse fields as computer sciences, material sciences, biology, arts, and psychology. Between 2007 and 2009, the period of our study, the lab employed on average 20 Ph.D. students and 3 to 4 postdocs. Moreover, it hosted two to three long-term visitors.

The AI Lab conducts basic research to gain a better understanding of natural and artificial forms of intelligence to work out the fundamental principles underlying intelligent behavior. To achieve this goal, the lab members explore how behavior emerges from a subtle interplay between the brain, the body, and the environment. This embodiment approach is the main research paradigm at the AI Lab (Pfeifer and Bongard 2007). Accordingly, the lab members reject the classical Cartesian position that behavior is the mere result of brain processes ("intelligence as computation"). Instead, they see nature as a rich source of inspiration for approaching questions of intelligence and show that "behavior emerges from the interaction dynamics of agent and environment through a continuous and dynamic interplay of physical and information processes" (Pfeifer and Bongard 2007, p. 284). Methodologically, the lab members pursue a synthetic approach of what they call "understanding by building." In practice, this means building robots of various materials and morphologies to mimic human and animal behavior. Rather than specifying functionalities ex ante, they constantly create, modify, and adapt behavioral systems as these develop. The Crazy Bird robot is a good example for the coupled evolution of a robot's morphology and its controller in response to the environment.[1]

The AI Lab has been a place for cutting edge research for the last two decades, acknowledged for its continuous production of new and unconventional ideas in artificial intelligence and robotics. We consider it, therefore, an extreme case well-suited for a single in-depth case study (Eisenhardt 1989). Maggie Boden, professor of cognitive science at the University of Sussex, affirms this stature: "The Zurich AI Laboratory is nothing if not controversial. Right from the start, it has tackled hotly disputed issues—sometimes adopting highly unorthodox methodologies. In short, it has not only been a shaker but also a mover" (AI Lab 2007).

Besides the continuous production of new ideas, the AI Lab is stamped by the heterogeneity of contexts in which it acts. Lab members are engaged in research, teaching, public relations, and industry relationships. This setting allowed us to study the recurring patterns that characterize routines and their interaction as multiple actors enact them through time and space. Last but not least, the ontological and epistemological premises of the AI Lab make it an ideal field site. The employed embodiment concept delivers a behavioral foundation for and a theoretical conceptualization of the understanding of agency and performative aspects (Latour 2005). Similar to the practice-based view in organization research, it provides an alternative to the cognitive perspective that seeks "to explain organizational conduct and phenomena as something stemming from the mind" (Nicolini 2013, p. 7).

Data Collection

Our fieldwork took both an organization-wide and a project-based perspective. Throughout the study we gathered data in the form of observations, informal and formal interviews, and documents. Our aim was to learn as much as possible about the recurrent daily activities of the different lab members.

Observations. We began our study at the AI Lab by attending lab meetings and formal group gatherings. After an adaptation phase of several weeks, the first author (KS) started to conduct regular observations, while the second author (SG) joined in occasionally. During the three-year observation period our presence at the lab differed in terms of intensity, ranging from half a day to five days per week including evening activities. From the outset the AI Lab provided KS a workspace, though she often moved from one office to the next. Because the lab staff was habituated to welcoming researchers with different backgrounds and different tasks, KS observed that she was accepted easily. Another important factor was the

intrinsic curiosity of the lab members about our research project and their role within it. It took only a short time before they ironically started to announce KS's presence as "big sister is watching you." After a while, the lab members behaved as if KS were an integral part of the team. In this environment, she quickly established formal and informal ties and gained an understanding of the daily work and culture of the lab.

Initially, the fieldwork focused on the observation of day-to-day activities, either by following certain people or by tracking ongoing research projects. KS watched how the researchers built robots, how they tested specific functionalities, how they developed new solutions for technical or functional problems, and how they presented their work to different audiences. She regularly went for lunch with various lab members, joined them for an after-work drink, or met them at parties. Whenever possible, KS attended internal meetings including the periodical lab meetings, progress and paper reports, brown bags, and project-specific meetings. She also joined meetings with potential industry partners, other scientists, and journalists. Outside of the lab's hallways she attended classes, conference talks, public events, etc. On these occasions, she observed how the lab members conveyed the meaning of their projects to students, experts, and laypeople. Throughout the study, KS took field notes.

Interviews. Our observations led to many informal discussions. In addition, we arranged formal interviews with the lab director, several senior scientists, and doctoral students. These interviews helped us to gain an understanding of the lab as an integral entity, its specific projects, and the particular routines present in everyday activities. All in all, we conducted 19 semi-structured interviews over the entire observation phase—3 with the lab director each lasting more than 2 hours and 16 with senior scientists and doctoral students lasting for about 1 hour. The first two interviews with the lab director were conducted approximately six months into the study, and the third one was conducted toward the end of the observation period. Most interviews with senior scientists and doctoral students took place during the second and third years of the study. All interviews were embedded in an ongoing discussion, meaning that they built on earlier exchanges and often led to follow-up discussions. According to the level of seniority of the interviewee, the structure of the interviews differed slightly. Ph.D. students told us about their academic background, how they came to join the lab, and their specific role in it. We inquired about the facts and figures of their projects and the teaching activities they were involved in. We urged them to describe a regular working day by telling us what exactly they did, why, and how. We asked specific questions about the writing process of a funding proposal or about the difficulties encountered in the building of a new robot. At the end of each interview, we asked Ph.D. students about their perception of the AI Lab and its position in the scientific community. Interviews with senior scientists followed the same structure but focused more on how they interacted with the Ph.D. students, their role in the various projects, and their position within the AI Lab. The open-ended interviews with the lab director were broader in the sense that we sought to understand the history of the lab, past decisions, and future directions. In the second and third interviews, we also asked questions related to the identified routines.

Documents and Artifacts. We collected a variety of documents and artifacts to support our observations. We gathered research proposals, reports, publications, meeting protocols, internal emails, photos, etc. We also took pictures of robots and videotaped construction, testing, or presentation procedures. We collected media articles and TV reports about the AI Lab in particular and on advances in the field of AI and robotics in general. These documents gave us some insights about periods during which we were not as frequently present at the lab. The main document sources are listed in Table 1 together with an indication of the covered time span and the number of items in each class of document.

Data Analysis

Initially, our research was driven by the question: Why are organizations able to keep up their innovativeness over time and across contexts? In particular, we were interested in how people do innovative work. Following an inductive and open-ended research design (Strauss and Corbin 1998), we oriented our search toward mechanisms that allow for flexibility and change. A theme that sparked our interest was the existence of multiple routines. We noticed in our data that many lab members reported similar practices, which guided their everyday activities. Thus, while we were looking for flexibility and change—factors that are commonly attributed to an organization's capacity to innovate—we found recurring action patterns (Feldman and Pentland 2003). With the interest in the role of ecologies of routines for innovation in mind, we iterated between the empirical material, the emerging observations, and the existing literature (Locke 2001) and decided that this focus was worth pursuing.

Our data analysis progressed in three phases: (1) the identification and analysis of routines; (2) the identification and analysis of actants connecting routines; and (3) the comparison of the engagement of these actants across projects. Throughout the data analysis process, KS coded, analyzed, and wrote the descriptions, while SG challenged the emerging codes to have robust patterns and to validate the findings.

In the first phase, we set out to identify the routines relevant for the AI Lab. KS coded the data to capture the actions that constitute the lab members' regular working days. This initial coding generated a list of recurrent

Table 1 Overview of Documents

Sources	Title/Description	Years (Items)
Books	Books by Pfeifer and various coauthors	2001–2007 (3)
Journal articles	Published by members of the AI Lab	1985–2010 (57)
Funding proposals	Abstract and/or full proposal (SNSF and EU)	1986–2011 (39)
Project handouts	One-page descriptions of ongoing research projects	2008 (11)
Lectures	Introduction to AI, neural networks	2009 (15)
Presentations	Public speeches mainly targeted to laypeople	2007–2010 (6)
Press reports	Articles, documentaries about the AI Lab	1995–2010 (96)
Emails	Internal emails on various topics	2007–2010 (>1000)
Meeting minutes	Protocols of internal lab meetings	2001–2008 (81)
Brown bags	Program including abstracts	1995–2008 (237)

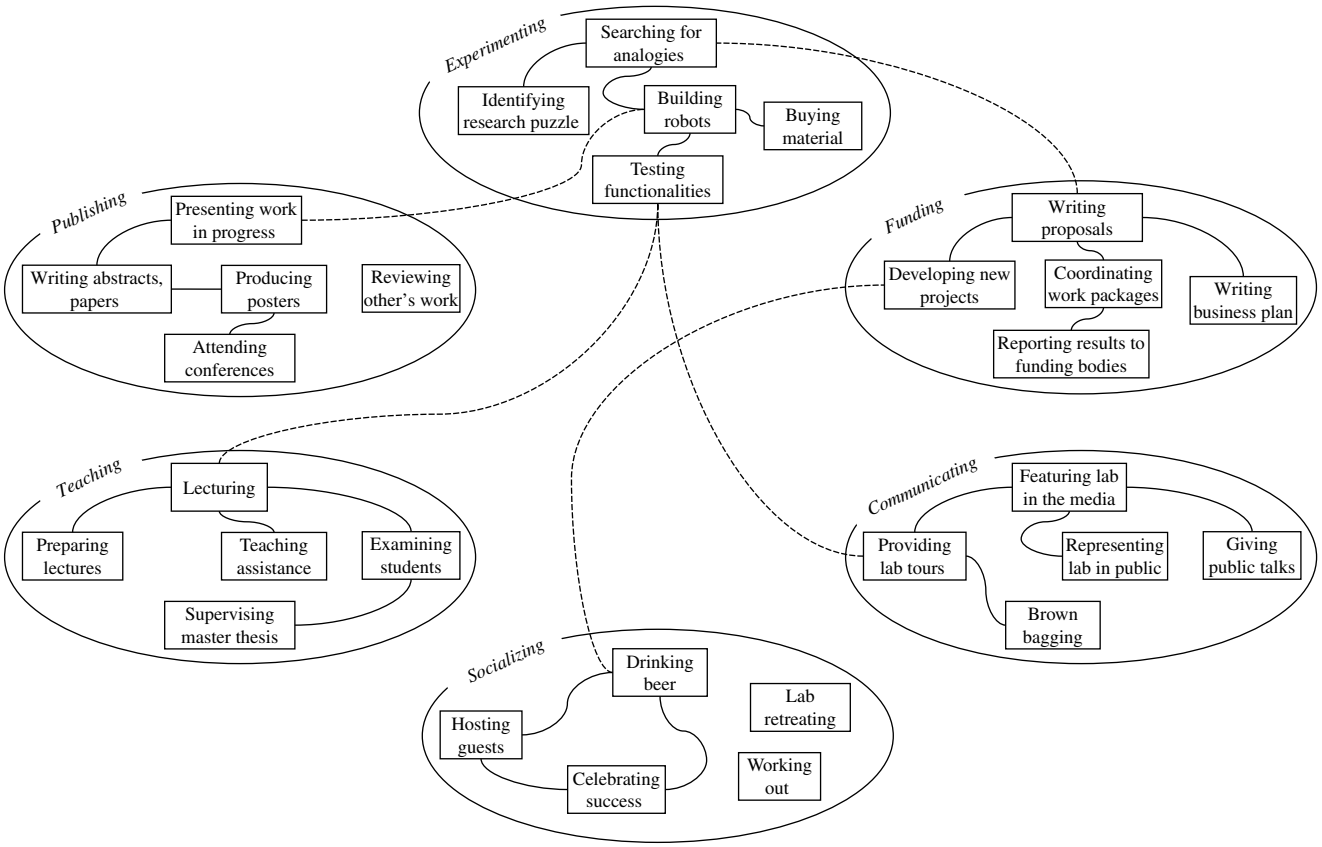
actions, which we discussed and gradually combined in a data reduction process (Strauss and Corbin 1998). In a next step, we reviewed the patterns to eliminate those that were not in line with Feldman and Pentland's (2003, p. 95) definition of routines as "repetitive, recognizable patterns of interdependent actions, carried out by multiple actors." For example, we eliminated the hiring of Ph.D. students or the management of project budgets from the list of action patterns because those tasks were performed by specific individuals rather than multiple actors and characterized by dispersed rather than interdependent practices. Overall, we identified a bundle of 30 routines describing the core activities of the lab members. Based on the identified routines, KS went back to the original data sources and wrote descriptions of the routines for a detailed within-routine analysis. For this purpose, we relied on the methodology of narrative networks introduced by Pentland and Feldman (2007) to create descriptions of routines by taking them apart down to the level of actants and actions and by asking questions of what, who, when, why, and how.

At this point of analysis, we presented the descriptions of the routines to various lab members to validate and refine them (Lincoln and Guba 1985). We relied on Schatzki (2011) and his classification of connections between practices to further group and characterize the identified bundle of routines (Feldman and Orlikowski 2011). As summarized by Figure 1, we grouped the routines according to six core tasks of the lab: experimenting, funding, publishing, communicating, teaching, and socializing. Within task categories the different routines are often connected through logical chains of actions (e.g., the testing functionality routine logically follows after the building robot routine). Across task categories, routines may be connected by sharing a common time space (e.g., drinking a beer as part of the partying routine coincides with discussing ideas for a new project), or by the intentionality of the actors who perform a routine to imagine something about another routine (e.g., while attending a brown bag seminar lab members imagine how the presented research can be made valuable for their building robot routine).

In the second phase, and when applying an across-routine perspective, we realized that a large set of human actors (including their knowledge and skills) and nonhuman actors (e.g., robots, materials, definitions, or money) played an important role in connecting the different routines. By connecting we mean that the actants emerged as outcome of specific routine performance(s) and were subsequently engaged in other routine performances. Analogous to the concept of "resources in use" developed in Feldman (2004) and described in Feldman and Orlikowski (2011), actants perform connections between routines and thereby realize the connection potential inherent in the specific bundle of routines of the AI Lab. Consider the photo of a prototype that emerged from the building robot routine and is integrated into a funding proposal to illustrate the current state of knowledge in a particular field of AI, or the share of money earned through the lab touring routine that is used to buy beer for the next potluck party, or the brown bag speaker whose advice is sought for the construction of a new robot. To gain an in-depth understanding of these actants at work, we wrote narratives of the different projects and their development. We employed a visual mapping strategy to trace actants that connect routines and to focus on what happened when the actants entered the routines and became part of their performance (Langley 1999). This analysis revealed that the different projects not only relied on the same routines but also on the same or at least on a similar set of actants. However, the way the actants were engaged differed markedly across the projects, leading to more or less generative routine interactions.

This insight led to the third phase of our analysis, in which we compared the engagement of actants across projects using an embedded case design to obtain the necessary variations for analytical comparisons (Yin 2003). Relying on Latour's (2005) distinction between actants that become either intermediaries or mediators in their situative engagement, we analyzed the engaging practices in the connecting of routines and how mediators led to different generative effects.

Figure 1 Core Routines and Exemplary Connections Within and Across Task Categories



Notes. The identified *routines* (*boxes*) constitute important practices of the everyday functioning of the AI Lab and are grouped into six *task categories* (*ovals*):

—*Experimenting*—Task to gain new scientific insights through empirical exploration and testing.
—*Funding*—Task to finance the lab besides the resources that are provided by the university.
—*Publishing*—Task to communicate scientific results that stem from the different research projects.
—*Communicating*—Task that enables the lab to position itself outside the scientific community and to spark interest for their research.
—*Teaching*—Task to teach different subjects related to the AI Lab internally at the university or externally.
—*Socializing*—Task to gather and exchange internally as well as with external guests.

The identified *connections within* (*continuous lines*) and *across* (*dashed lines*) task categories are illustrative and by no means exhaustive.

Findings

To examine the issue of how actants in performing routine connections become either mediators or intermediaries and thereby do or do not enable new things to emerge, we compare seemingly similar routine interactions and show that they may lead to different outcomes. Because it is impossible to offer a detailed account of all the projects analyzed within our study, we focus on two of them and provide three vignettes that illustrate the ways actants connect routines through their situative engagement in routine performances, why the connecting was more or less generative, and what resulted from this generativity.

Actants Performing Routine Connections

The Adaptive Leg Press (ALP) project and the Development of a Robot Kit for Education, Art, and More (DREAM) project were both launched in 2007 as strategically important initiatives of the AI Lab. The director allocated the necessary resources to these projects and used them for demonstrating how the embodiment paradigm can be fruitfully applied in AI research. Both projects targeted a variety of stakeholders including the scientific community, the industry, and the general public and, importantly, both aimed not only at scientific results but also at attracting the attention of potential investors and users in the long run. Our data analysis reveals that the two projects relied on a similar and relatively persistent bundle of routines. That is, the changes the bundle underwent over the course of our study are limited as the action patterns perpetuated over time. Further, toward the end of our observation, both projects emancipated themselves from the AI Lab. Yet, retrospectively, the two projects differed markedly in terms of generating new concepts, methods, and materials, in terms of producing new knowledge in the form of scientific publications or patents, and in terms of commercial success; all factors that Salter and Martin (2001) identify as crucial for evaluating the generative potential of basic research.

Whereas the ALP project quickly gained momentum and has been successful in commercializing a training robot, the DREAM project did not result in any measurable commercial success. The main innovative outcome of the ALP project is the leg press itself, which integrates several new concepts and materials such as the use of pneumatic actuators for training machines or the integration of a video game that directs the exercising. In 2010, the first ALP machines were sold, and a patent was filed to protect the further development of the training machine. Scientifically, one of the two protagonists of the ALP project managed to publish several articles in top-tier journals and conferences on bio-inspired robotics and embodiment. The DREAM project, on the other side, resulted in only one conference proceedings paper and one book chapter throughout the time of our study. Moreover, the project team could not attract the interest of the industry. So, whereas the overall goal of the project seemed rather clear at the beginning, the practical implementation was challenging because the protagonists had difficulties integrating the educational aspects into the regular robot building approach of the lab.

We shall now turn to a short description of the two projects to provide a dynamic account of the situative effects of actants and their connecting. The narratives will be followed by a zooming-in on specific actants and how these were differently engaged.

ALP Project. Two researchers of the AI Lab launched the ALP project with the vision to build a training machine that would incorporate the state of knowledge in sensory motor research. The initial idea for the ALP emerged when a newly hired postdoc began weight lifting at the gym with a Ph.D. student. While doing the leg press, the two researchers discussed "how what we knew from our research on sensory-motor tasks was not applied in training machines" (postdoc). Back at the lab, they continued to reflect on the idea that there must be ways to achieve smoother and less mechanical body movements. The researchers quickly gained an understanding of conventional leg presses and, in consultation with the lab director, they initiated a research project aiming at a future commercialization to study how robots and machines adapt to each other: "Embodiment up to now has been about building robots and trying to prove concepts. And how we are trying to bring the user [people] back into the loop" (Ph.D. student). For constructing the prototype, they drew on pneumatic actuators already used in an existing robot. Following the sparking interest on human–machine interactions, they modified their construction practices following an engineering-driven approach.

Early on, the ALP project was an integral part of lab tours that allowed interested people to visit the lab, marvel at the robots, and engage with the researchers. During the tours, they let the visitors test the prototype—a practice that allowed them to spot problems and to build up a repertoire of selling arguments that became very useful later when writing a business plan and communicating with potential investors. Among the visitors were athletes of the Swiss national ski team, who became regular testers and eventually bought the first leg press. Other visitors hosted by the AI Lab also became part of routine performances. For example, the dancer Pablo tested the ALP and commented on the movements from the perspective of human anatomy. Pablo provided several fresh insights that helped in refining the prototype to make the training movements mimic body posture even better.

In parallel, the researchers engaged in writing a funding proposal for the Swiss National Science Foundation (SNSF) to develop the scientific aspects and to put the project on a financially viable basis. To do so, they relied on a set of research questions, the first prototype, as well as on existing arguments taken from old proposals. Whereas the proposal was rejected, it can still be considered an important step as the reviewer feedback pushed them to turn toward a commercial logic in furthering the development of their project. Shortly after, they engaged in writing a business plan. When starting to write, they worked with a template that they gradually filled in. However, certain aspects like the financial planning were beyond their savvy, leading them to ask experts for help. We, for example, helped in developing the marketing part by providing them with our knowledge and reading of the situation, pointing to the importance of facts and figures, and the need to structure their argumentation along established marketing concepts. In 2009, the ALP project turned into a spin-off company and moved to a nearby technology park.

DREAM Project. The DREAM project was aimed at the development of a robot kit for students based on modular robotics. The key idea—first developed during a lab retreat—was to provide an alternative to existing commercial robot kits with their fixed architectures; one that would integrate the concept of embodiment: "I mean if you go to our lab you have a project on self-assembly, you have one on the prosthetic hand, etc. Is there something like a common denominator in all these projects? Someone suggested education and I said, 'Oh wow!' That's actually very interesting because if you want to teach something you really have to know what the underlying concepts are" (director). Accordingly, the researchers started out by familiarizing themselves with the educational robots market and compared various commercial robot kits by assembling them and trying to understand their strengths and weaknesses. Engaging with the commercial robot kits led one of the Ph.D. students to transform an existing theoretical seminar on AI into a practical teaching module within which students built their own robots using one of these kits. The seminar became very popular, but despite the grad students' enthusiasm

and commitment during the seminar, the researchers were unable to mobilize them for their project, e.g., to write a master's thesis on a subtask. The grad students just did not perform the potential routine connection.

Simultaneously, the researchers started to write a funding proposal for the SNSF. They based their research questions on preliminary insights and borrowed existing arguments from old proposals. The proposal was rejected in three consecutive submissions, although much of the reviewer feedback had been taken into account in the revision processes. For example, they integrated new ideas based on a collaboration they initiated with educators and artists—to no success. Despite (or maybe because of) the disappointment, the director decided to keep the project alive through cross financing and started to push the protagonists into participating and organizing public events during which robots were demonstrated to visitors; a task that the researchers executed but interpreted as distraction from their project.

In a second phase, the researchers started to build their own robots based on existing robots and components developed at the AI Lab. Compared to other projects, however, it took an extremely long time for the first stable prototypes to emerge, and many interlinked activities such as testing functionalities, paper writing, or establishing collaborations had to be set back as a consequence. It was only after a random encounter that the project entered a more generative phase. One day, an administrator sitting in the AI Lab's hallway recommended one of the Ph.D. students as instructor for a special informatics course to high school teachers. Instructing the course led to follow-up interviews, which in turn helped to better understand the needs and difficulties in teaching robotics. The interviews provided many insights for the building of educational robots and opened new ways to advance the project. Over time, prototypes emerged and were tested in workshops with art students, schoolchildren, and members of the general public.

Six years into the project, the principal investigator defended her Ph.D. and returned once more to the proposal writing routine. To further develop the project, she applied for a fellowship to visit the Center for Engineering Education and Outreach at Tufts University. The proposal benefited from incorporating validated knowledge and from an already established contact with colleagues at Tufts. This time, the proposal was accepted, and the funding money enabled her to pursue a postdoctoral fellowship. The fellowship was beyond the horizon of our observation, however.

Routine Interactions—The Same, Only Different

The above descriptions have illustrated that routine interactions—that is, performed routine connections—are not only ubiquitous; they are an integral part of how new things emerge in and over time. A Ph.D. student described the emergence of new things and the aggregation of generative connections as follows: "You read a lot and people come to give brown bags and you see things during lab tours. And once you kind of accumulate some things that you have seen, then the ideas pop up." Putting it in abstract terms, the Ph.D. student described his permanent exposure to actants; invoked in daily routine performances. These actants literally move through the lab, because they are taken up in the performance of another routine or the subsequent performance of the same routine. The way actants operate differs from engagement to engagement; i.e., they are more or less generative depending on their situative engagement. It is impossible to offer detailed examples of all the actants we found. Instead, we present three vignettes. Each vignette traces a different actant, showing how the actant becomes either a mediator or intermediary through the way it is engaged in routine connecting and how this leads to differences in generativity.

Vignette 1: *Reviewer Feedback—Connecting Writing Proposals and Developing Projects.* Reviewer feedback is a direct and observable outcome of the writing proposal routine. After a proposal is submitted, it is evaluated by one or more reviewers and the funding bodies decide upon which projects they will support and send decision letters including the reviewer feedback to the applicants. In our cases, funding proposals were written after the project had already started. The proposals were rejected once (ALP) or even several times (DREAM). This did not, however, jeopardize the continuation of the projects. On the contrary, the projects continued even when it became apparent that there would be no external funding: "It was never a problem for the director that our project [DREAM] did not receive external funding" (Ph.D. student).

Both research teams took up the reviewer feedback in their developing project routine: "The way I like to do this is listen to them [the reviewers] and then ask ourselves how we can turn that into a better project" (director). In concrete terms the reviewer feedback resulted in lab-internal exchanges as well as in making contacts with potential partners outside the lab. Thus, we consider the reviewer feedback as inflow of ideas the researchers engaged with in their discussions on how to further develop the projects. As we show now, the way the researchers performing the routine engaged with the reviewer feedback differed markedly between the two projects.

Engaging practices—ALP. The reviewers of the ALP project criticized both a lack of scientific rigor and focus as well as a lack of cooperation with partners from the field of sports science, who could have brought in the necessary knowledge about exercising. At first, the two researchers were very disappointed by the rejection of their proposal. However, reading and discussing the reviews carefully and going back to what they had proposed, they realized that

the reviewers' suggestions would require a very narrow focus on specific scientific aspects. This contradicted how they so far positioned and envisioned the project, namely as a basic research project on human–machine interactions that could potentially lead to a commercialization in the future: "We are confident that this kind of research always has some kind of side products that can be marketed" (Ph.D. student). Hence, they decided that it was not worthwhile to engage in another writing process.

Nonetheless, the researchers appreciated the proposal writing process as valuable input for the further development of the project: "We had to think about the tasks and the writing was very helpful, as now we can really focus on what we want to do." The reviewer feedback made them realize that they would need to emphasize the commercial aspect and to shift the focus from the robot as such to the exercising person as a user of the machine.

The reviewer feedback became a *mediator* when the researchers actively took up the "commercial logic" arguments raised in the developing project routine and engaged them in defining the future orientation of the project. Subsequently, they positioned the ALP as an applied research project with the ultimate goal of developing a marketable product. The director also changed his discourse and started to speak more and more about the commercial potential: "We are talking to Kieser Training [worldwide fitness center chain] about this and they seem to be interested. Many people see a real commercial potential."

Engaging practices—DREAM. The researchers of the DREAM project received and had to engage with negative reviewer feedback in three submission rounds in a row. One of the main issues raised by all review reports was that it did not become clear from the proposals how they would achieve the goals of the project: "There seems to be a mismatch between theoretical underpinnings and identified deliverables" (review report). It was not that the reviewers opposed the idea of an educational robot kit, but they consistently pointed out that the project had been set up in a way that did not match with the intended outputs: "I had high expectations when I have been asked to review this project since Pfeifer and Siegwart constitute some kind of 'dream team' in innovative robotics. However, I have special concerns about the status of education in this project" (review report).

In the first round, the reviewers urged them to build up interdisciplinary collaborations to ensure the promised deliverables. In response, they got in touch with artists from the Zurich University of Arts and educators from the University of Teacher Education in Bern. They met with representatives of both institutions to reflect upon a possible collaboration on the DREAM project. Yet, in spite of several meetings and brainstorming sessions, the collaboration remained superficial and there was a lack of clarity on who would contribute what and how. This becomes evident from the revised proposal in which the AI Lab team highlighted the interdisciplinary collaborations but did not allocate any financial resources to the collaborating institutions. The only reason for proposing these collaborations was the targeted funding.

The failure to engage the partners reflects how the researchers engaged with the reviewer feedback. Whereas they read the review reports and reflected upon how they could address the issues raised, the feedback still became an *intermediary* because the researchers considered it fundamentally inappropriate and hence refused to integrate it in the argumentation of the overall project: "I talked to a number of people and told them about the project. They were all extremely excited about it. I mean everybody likes the project, and we don't seem to be able to get money for it. We must be doing something fundamentally wrong [in writing the proposal]. And honestly, I don't know what" (director). In other words, the researchers integrated the reviews pro forma and without being convinced about their merit. So, whereas in each round they marginally adjusted the proposal to account for the comments, they continued to conduct the project as initially set up.

Vignette 2: *Robots—Connecting the "Robot Zoo" with Building Robots.* Building robots is a central routine at the AI Lab that plays an important role in almost any project. Over the last 25 years a large "robot zoo" has emerged, not only documenting the progress made but also functioning as a reference guide for future research ideas. An external scientist commented on the multitude of robots: "Rolf and his collaborators made their point with the development of a zoo of jumping forks, deformable compound eyes, and other springy creatures whose mechanical properties transformed environmental interactions into meaningful behavior without programmed control." The building robot routine starts out with first sketches, before the lab members engage in constructing and deconstructing by soldering and other methods of assembling: "Researchers at the AI Lab belong to a new generation of scientists with a working method more familiar to sculptors and tinkers" (external scientist). During the constructing efforts, researchers exploit the properties of different materials to achieve specific behaviors in the emerging prototypes.

The researchers in our two exemplary projects drew on existing robots, the pneumatic robot arm, and the robot dog Puppy, as starting points for their own robot building. The two robots are not the outcome of a routine performed within the projects. Instead, they were engaged out of the "robot zoo," which serves as common resource to all researchers at the AI Lab. Both robots were fully developed and operational when they became engaged within the ALP and DREAM projects, respectively. Acting as flagships for the AI Lab's research on understanding intelligent behavior (Pfeifer and Bongard 2007), both robots are often referred to in presentations, papers, or funding proposals. Despite the similarities in the observable qualities of the robots, their engagement within the two projects was again very different.

Engaging practices—ALP. When beginning to imagine how a more adaptive leg press could look, the researchers discussed not only the machine; they also reflected upon what kind of materials would enable the properties they were looking for. One idea was to draw on the pneumatic actuators from the robot arm, which can convert energy into mechanical motion. Indeed, the Ph.D. student had been involved in an earlier robot arm project and therefore was familiar with the functioning of the actuators: "I became interested in pneumatic solutions because I was working with company F on a robot that needed a lot of power and at the same time a low weight ration. I found this rubber, and combining it with pneumatics led to contractions that resemble those of human muscles."

The team envisioned that these parts could be the counterpiece of the human leg muscles, leading to the needed connection between the machine and the human body. Accordingly, they started to convert parts of the robot arm and build them into the leg press. Early on they realized that the dynamic uptake of energy facilitated by the pneumatic actuators led to a new quality of exercising because the elasticity of the actuators led to much less mechanical movement by the trainee. However, the use of the actuators also required a refined balancing of the forces that occur inside the machine. The latter insight had a direct impact on how the robots are built, because the machine needed to be extremely stable and reliable to prevent dangerous movements that could potentially hurt the body of the trainee.

The existing pneumatic actuators became a *mediator* in the ALP project. The researchers reinterpreted them to construct a very stable and secure training machine. In doing so, they questioned the underlying construction philosophy of the AI Lab, which was rooted in a bricolage approach: "We [at the AI Lab] build things in a way that they must fall apart" (senior researchers). For their project, they followed an engineering-driven approach that implied an in-depth testing of the materials used and the implementation of new fixture methods—changes in action patterns that were not taken up by other projects at the lab.

Engaging practices—DREAM. After initially engaging with existing commercial robot kits, the DREAM researchers started to reflect upon how existing robots could be used to build their own robot kit. The idea was that, by relying on existing robots, they could focus on rendering the robot modular without the burden of constructing an entire robot from scratch. As in other projects at the AI Lab, they reused the robot dog Puppy, which incorporates many aspects of the embodiment approach because his movements are, to a large extent, driven by his morphology.

The researchers sought to build a smaller version of Puppy. Early on they figured that "the way Puppy was built was not really compatible with the requirements in the classroom. A major problem for us is that the robots built at the lab are not robust enough to be the basis of a robot kit" (Ph.D. student). Further, they mentioned, "to be useful in workshops, the robot needs to be much more modular. It is, for example, totally inconvenient if the legs are not symmetrical or if the controller cannot be easily detached." Whereas they spotted the challenges of relying on Puppy (or another AI Lab robot), for a long time they were unable to translate their reading of the situation into constructing a functional robot. For example, whereas they deconstructed Puppy and focused on specific parts of the robot (the legs), the robot as a whole and his functionalities (e.g., the ability to run fast because of its morphology) remained the reference point. This became evident when they were doing sketches and presented the progress of the projects at the lab. A photo of the original Puppy was used and they added colored shapes to show which parts they want to work on, meaning that they envisioned Puppy as a whole instead of a modular reference. When they talked to us, we could sense their frustration about how the researchers who originally built Puppy provided them with components and materials but did not become implicated in the DREAM project itself: "MH passed me on ski climbing skins they had used to put onto the feet. But the general rule was that I had to learn everything on my own" (Ph.D. student).

In the DREAM project, Puppy became an *intermediary*. Whereas the researchers interpreted the robot in the light of how and why it had initially been constructed, they had difficulties rethinking Puppy's constituting parts and adapting it to the DREAM project. Accordingly, we witnessed a mere transfer of existing knowledge that was integrated into Puppy, feeding into the building robot routine without creating something new.

Vignette 3: *Visitors—From Lab Touring to Testing Functionalities.* The testing of functionalities is another key routine in the advancement of projects. There is a direct connection between the latter routine and the building robots routine, because they build on each other. Apart from this obvious connection, the testing functionality routine also holds a less expected but recurrent connection with the lab touring routine. Lab tours offer visitors the opportunity to exchange and discuss with the different researchers at the AI Lab. Groups of students, politicians, business people, and journalists tour the lab almost weekly and are provided with insights from the different projects. As the director explained, the lab tours are beneficial for both sides: "If you have to explain what you are doing to a general public, then you really have to understand what you are doing. I mean, then you cannot just come with technical issues, but you have to be able to explain the essence of what you are doing."

Since there is a regular inflow of visitors who are invited to talk to the researchers in their offices and experimenting spaces, they potentially turn into an integral part of the testing routine. We observed that the researchers

often planned tests on the same day as a lab tour took place to properly set up the experiment and to provide visitors with real experiences. Of course, the lab members differed in their appreciation. Whereas some considered lab tours a time-consuming obligation, others were able to take advantage of the visitors: "Actually it's a cool thing because for us it's kind of easy to present stuff to the general public. We have robots that are real and you can grasp the mechanics behind it immediately. And sometimes the visitors ask useful questions" (Ph.D. student). As we will see below, the way visitors were engaged differed across the two projects.

Engaging practices—ALP. The ALP team regularly participated in lab tours and invited the visitors to do a short training session on the leg press whenever possible. These sessions did not provide new scientific insights but helped the researchers to better grasp what people like and do not like about the leg press, offering direct user feedback.

One day, the athletes and coaches of the Swiss Olympics team visited the lab to have a look at the ALP. During this first encounter the athletes tried out the machine and discussed its advantages over conventional leg presses with the researchers. Several athletes were enthusiastic about the machine, and the researchers took the opportunity to start collaborating with them. From then on the athletes came frequently to the lab for extensive training sessions and to sense how the ALP could enhance their regular training. A coach commented, "the ALP fills a significant gap in the training and rehabilitation of our top athletes." The training data was recorded, analyzed, and taken up for improvements of the prototype, and the athletes were thus able to track their training results while the researchers gained an in-depth understanding of the needs of top athletes, leading to adaptations of both the hardware and the software of the ALP as well as to the idea to start selling the leg press based on first expressions of interest by the athletes.

The visitors, and in particular the athletes, became *mediators.* The researchers considered and treated them as part of the team who would provide valuable insights for the testing functionality routine and for the project as a whole. The intense interaction with the athletes and their coaches led the researchers to adapt and extend the testing functionality routine to work with external people and to meet their specific needs. By appropriating the perspective of the athletes, they engaged in a user-driven logic to pursue the testing. Further, this collaboration accelerated the commercialization process and eventually resulted in the emergence of a new routine within the AI Lab—writing a business plan. Despite the fact that there have been commercial ideas and aspirations in past projects, none of them developed to the point that writing a business plan seemed appropriate.

Engaging practices—DREAM. The researchers of the DREAM project also participated in the lab touring routine. Moreover, they frequently represented the lab in public events or co-organized large lab tours. Depending on the format, the researchers either presented robots from different projects (not just their own) or held special robot building sessions. For the latter purpose they refined and adapted the format that they had developed for the AI seminar to conduct the workshop on a single day. For example, the researchers carried out such a workshop during the AI Lab's anniversary. The workshop was targeted at children who wanted to learn more about AI and to build their own robot: "In groups of two you will build an Asuro robot from scratch (duration ca. 5h) by soldering each electrical component onto the board on your own. Then, we will show you how to handle the sensors and motors using a simple C program. At the end of the workshop, you can take the robot along" (event flyer). Although this sounds exciting, the interaction with the participating children stayed at a rather technical level and had no impact on the everyday performance of the testing functionalities routine of the team. One of the Ph.D. students explained, "I found it very difficult to be a teacher. [. . .] I'm a geek, I like to construct, I'm not a social scientist."

Three years into the project things started to change, as the researchers realized that visitors could potentially provide interesting insights. For example, they created a survey that was distributed to participants after robot-building sessions. This allowed them to gather user feedback and to better understand the problematic aspects of the robot kits in use. In combination with the development of their own robot kit prototype, the workshops slowly turned into a testing field that pushed the further development of the project. Only after the protagonists were able to align their engagement in lab touring with the goals of the DREAM project were they able to build testable prototypes, write convincing conference proceedings, or gather funding based on the knowledge produced. So, visitors, who at first became *intermediaries* as the researchers considered and engaged them as actants at the periphery of their project and did not truly integrate them into their testing activities, turned into *mediators* through their generative engagement.

Mediators and Their Generative Effects

As shown above, actants perform connections between the routines an ecology is composed of. The organization-specific bundle of routines constitutes the prerequisite for the connecting and, at the same time, the potential for actants to operate in a more or less generative way. Some of the identified actants are part, or even the outcome, of specific routine performances; others are engaged from the repertoire of actants, which we conceive of as a resource pool upon which people draw when performing routines. Over time, the repertoire is updated and enhanced, which

provides new engagement opportunities and ultimately new connecting potentialities.

Our vignettes show that whether actants become intermediaries or mediators depends on their situative engagement in routine performances. In the ALP project, several routine interactions led to the emergence of innovative outcomes such as the construction of a novel prototype, the establishment of a fruitful collaboration, or the writing of a successful business plan. In the DREAM project, on the other hand, for a long time the ongoing routine interactions did not result in the aspired outcomes; neither in a testable prototype, nor in publications or fruitful collaborations. Comparing how mediators and intermediaries connect routines allows us to theorize about how the engagement of actants influences their becoming and, ultimately, the generative effects of, mediators. As actants connecting routines unfold their generative potential in action only, their engagement is crucial for whether an actant becomes an intermediary or a mediator. Our study demonstrates that the engaging practices are based on the interpretation of actants in each specific situation. Empirically, we identified two ways of interpreting—in relation to a single routine to be performed and/or in relation to the bundle of routines that constitute an important part of the everyday practices at the AI Lab.

In the ALP project, we encountered routine interactions in which the researchers interpreted the actants in relation to both the immediate routine performance and the larger scope of the project, hence involving the bundle of routines practiced at the lab. For example, the reviewer feedback became an integral part of the developing project routine. At the same time, however, the researchers also related the feedback to the scope of the project and repositioned it accordingly. Hence, we may state that the reviewer feedback became a *mediator*.

The researchers involved in the DREAM project did not, or only gradually, link the two interpretations in engaging the reviewer feedback and the existing robot. The feedback pushed them into talking to artists and educators and to integrating these contacts into the subsequent proposal. Yet the researchers' interpretation of the feedback did not impact the dynamics of the project as such because they did not consider the new contacts a real part of the project. Rather, they considered the reviewer feedback on a routine level only. The engagement of the robot, on the other hand, was interpreted in light of the overall project goals, but the researchers failed to translate the interpretation into their own robot building process. Accordingly, both actants, the reviewer feedback and the robot, became an *intermediary*.

Based on these observations, we suggest that differences in the interpretation of the actants may explain differences in their generativity. Engaging an actant is about interpreting it throughout the performance of the ongoing routine and consistent with the scope of the project to alter the outcome of the routine. It is important for the performance of bundles of routines to account for this dual dimension of engaging practices, because the interpretative linkages are not automatic but unfold in action. Consider the engagement of visitors within the DREAM project. Initially, visitors were interpreted as part of the testing functionality routine only. Interpreted this way, they did not turn into a generative actant but merely reproduced the testing that the researchers had already done with the commercially available robot kits. When the visitors eventually were interpreted as a valuable source of feedback and as potential users of the aspired robot kit, they became *mediators* enabling innovative outcomes such as a conference paper.

Mediators had three different generative effects, resulting in: (1) innovative outcomes that often became connecting actants in subsequent routine performances and, hence, elements of the repertoire of actants; (2) adaptations of existing routine performances; and (3) emergence of new routine performances. All three effects could occur separately or in combination. Further, the effects could be generated by a single actant as well as by several actants becoming part of the same routine.

For example, the reviewer feedback connected the writing proposal routine with the developing project routine and helped in establishing the concept of commercial logic (type 1 effect). The researchers interpreted the commercial logic in light of the idea of human–machine interaction, which had so far driven the ALP project. The interaction between the two actants led to changes in how the training machine was built (type 2 effect). These changes were initiated by the reviewers' feedback and shifted the focus of the project from research to the commercial application. The researchers also invoked the commercial logic when they engaged the athletes in the testing functionality routine. Interpreting athletes through the commercial logic led to an adaptation of the routine (i.e., user-based tests) and resulted in a novel routine—the writing business plan routine (type 3 effect). Whereas at the time of our study neither the adapted nor the newly created routine was relevant to other projects, both became part of the AI Lab's repertoire of actants that could be engaged in the future.

We have focused on how mediators can render routine interactions and ultimately ecologies of routines more or less generative. This does not mean, however, that intermediaries are negative or of no value to organizations. On the contrary, they are of great importance for the functioning of any kind of organization because they embed organizational knowledge and past experiences, allowing the reproduction and stabilization of successful routines over time. It might even be that intermediaries are particularly important for innovative organizations such as research laboratories. For example, the turnover of people is extremely high at the AI Lab because most people leave once they have finished their Ph.D. This implies that intermediaries are an important aspect of the

long-term functioning of the AI Lab, because they allow reproducing the performance of the organization-specific bundle of routines in a constantly changing environment.

Discussion

Motivated by the interest of actual innovative work in organizations and the role routines may play for new things to emerge, our study of the AI Lab offers a detailed account of how actants performing routine connections can render the interactions more or less generative. As in other basic research laboratories, producing novel insights is one of the main activities of the AI Lab, allowing them to gain and keep legitimacy over time. Our study illustrates that seemingly similar routine interactions do not always lead to the same outcomes and that thinking and applying "the new" is an uncertain process that cannot be envisioned a priori (Latour 1987).

Our findings suggest that one factor for generativity is whether actants become intermediaries or mediators through their engagement in performing routine connections. All actants hold the potential of generative agency, meaning that they bear the potential to modify the routine performances into which they are fed, to trigger the emergence of new routines, or to bring about innovative outcomes. But not all actants unfold their potential in connecting routines, because it depends on whether or not the actant is able to transform and translate through its engagement, and thus become a mediator. The comparison of the engaging practices revealed that they are based in the interpretation of actants, both in respect to the interacting routines and the overall bundle of routines. It is only when the two interpretations are linked that the actants can unfold their full generative potential in action.

Our findings make three important contributions to the literature: (1) they enhance our understanding of ecologies of routines and their internal dynamics, (2) they extend our conceptualization of the role of actants in routine dynamics, and (3) they help us better understand the role of meta-routines and capabilities in innovation processes. We now review these contributions in detail.

First, our findings offer interesting insights for understanding ecologies of routines; a phenomenon that has recently received increased attention in organization research (Birnholtz et al. 2007, Salvato 2009, Turner and Rindova 2012). Whereas the existing studies focus on ecologies as such and how these operate, much less has hitherto been known about their internal dynamics and the role routine interactions play for generativity and organizational outcomes in general terms. We extend previous accounts of how such bundles of routines evolve and change by focusing on routine interactions and the performance of routine connections. Our study suggests that routine interactions hold generative potential mainly because of the connection potentialities, which provide the opportunities necessary for the emergence of new things. This finding underlines the basic idea of a performative perspective within which "one is asked to think in terms of nodes that have as many dimensions as they have connections" (Latour 1996, p. 370). Performed and aggregated, the routine connections potentially trigger innovative outcomes in the sense of a translation process.

Conceiving of ecologies of routines as dynamic also contributes to the research program on endogenous routine dynamics (Feldman and Pentland 2008). Our findings support the generative nature of routines and highlight the fact that these are mindful and consequential in terms of performance and outcome (Feldman 2000, Feldman and Orlikowski 2011, Levinthal and Rerup 2006, Pentland and Rueter 1994). Routines are not only essential for addressing repetitive tasks in established and stable environments; they play a major role in critical organizational processes and outcomes (Howard-Grenville 2005, Salvato 2009, Zbaracki and Bergen 2010). Based on our study we claim that it is not only the recursive interactions between the ostensive and performative aspects of a single routine that are potentially generative (Feldman and Pentland 2003), but also the continuous interactions between the routines constituting an ecology.

Our performative perspective might also provide interesting grounds for scholars who have begun to study capabilities from a micro-foundational perspective (Felin et al. 2012). Whereas these studies provide interesting insights, for instance, on individual actions and their role in producing sequence of actions (Pentland et al. 2012) or individual determinants of strategic capability building (Mäkelä et al. 2012), they are often caught up in their own conceptualization. Indeed, by focusing too much on foundations and entities at the micro-level, they are often unable to dissolve the micro–macro distinction or even aggravate it. To paraphrase Latour (1996): they are tied by order relations either acting top-down or bottom-up and by explaining the macro through the micro. Our study illustrates that tracing connections on a performative level and following the methodological call for "flat ontologies" might be fruitful in explaining organizational phenomena (Schatzki 2011).

Second, our focus on actants that connect routines and their engagement have implications for the way we conceptualize actants. Over the last decade, there has been an increasing interest in materiality and how it impacts organizational processes (Leonardi et al. 2012). In the realm of organizational routines, D'Adderio (2008, 2011, 2014) calls for a material turn and studies how artifacts influence the emergence and persistence of routines and, more in particular, how they mediate ostensive and performative aspects of routines. She points out, however, that we need to be cautious not to ontologically prioritize social or material aspects, but to apply a relational ontology that envisions both aspects as an assemblage (Orlikowski and Scott 2008).

ANT, and in particular Latour's (2005) distinction between intermediaries and mediators, is useful here because it does not focus on material or social aspects but investigates the functioning and effects of actants in their becoming (D'Adderio 2011). Our empirical findings support this conceptual distinction. It is not the right person or object at the right time or place that makes the difference. Rather it is decisive, so we argue, whether or not the actants involved in the routine interaction become mediators and impact the assemblage in a way that alters the course of events in one way or the other. Actants are not only "produced in relation" but also "performed in, by, and through those relations" (Law and Hassard 1999, p. 4). In the words of Pickering (2010, p. 191), we see "a dance of human and nonhuman agency" that mediates the interactions between routines. Accordingly, we contribute to the understanding of how artifacts influence change (i.e., innovate) and stability (i.e., replicate) of routines (D'Adderio 2014) by focusing on their role in routine interactions and on their generative effects that may lead to innovative outcomes.

Third, we contribute to the understanding of the role of routines for innovation by emphasizing routine interaction and its generative potential (Nelson and Winter 1982, Pavitt 2002). Historically, research dealing with an organization's capacity to innovate has been concerned with higher-order constructs such as capabilities or meta-routines, which are thought to either produce innovative outcomes directly (Hargadon and Sutton 1997, von Hippel et al. 1999) or to facilitate them by creating a stable environment for creative tasks (Becker and Zirpoli 2009, Ohly et al. 2006). These capabilities are not only seen as main drivers of innovation processes within organizations, but also as a hard-to-imitate resource that is responsible for an organization's competitive advantage (Eisenhardt and Martin 2000). Our study opens up the black box of capabilities and examines in more detail their internal dynamics. We show that the constituting parts (i.e., routines and actants) of the innovation capability are key to explain its actual performance and, therefore, the ability of the organization to innovate. Our study also demonstrates that generativity is by no means predictable and that a similar setup (i.e., a similar bundle of routines and connecting actants) can lead to very different outcomes (Garud et al. 1997). This supports the view that innovation needs to be approached as a serendipitous process, which unfolds in action only (Bijker 1995).

Limitations and Directions for Future Research

Our contributions point toward different areas for future research and highlight certain limitations and boundary conditions of our study. We have analyzed a single organization in a particular empirical setting—a university-hosted basic research laboratory. This setting has been very useful to study the generativity of routine interactions and the role actants and their engagement play. Yet, we acknowledge that comparing organizations in different contexts, especially those less driven by the search for novelty, might provide further insights. And whereas we are convinced that the ethnographic approach and the longitudinal character of our study as well as the embedded case design permits us to draw some generalizable conclusions, we encourage future research to compare routine interactions across different organizations and to see whether "it matters if these interactions are within versus between organizations" (Parmigiani and Howard-Grenville 2011, p. 447).

We have focused on the analysis of a specific bundle of routines. There is the risk that we overemphasized certain routines and understated others. This limitation relates to the fact that we have not paid particular attention to the role of managerial practices and how these influence the enactment of bundles of routines. Our observations suggest that the director and the senior staff of the AI Lab shape not only the identified routines, but also encourage their continuous performance as well as the engagement of actants. Future studies may pay particular attention to managerial practices and their power in influencing routine interactions and, consequently, organizational outcomes.

In the present study, we have focused on individual actants that connect routines and enter specific routine performances. Yet we have only marginally studied the relationship between the actants and they might, of course, influence each other. Therefore, we encourage future studies to consider how actants interact when connecting routines and how this affects their generative potential. Overall, we support the call by Salvato and Rerup (2011) for more research on ecologies of routines, on routine interaction, and the implied interdependencies of routines and actants.

Conclusions

Prior research has emphasized the importance of higher-order routines for an organization's ability to innovate and how ecologies of routines evolve over time. In this study, we have demonstrated why differences in the interaction of the organizational routines of a basic research laboratory are crucial for understanding how and when generative outcomes potentially emerge. By comparing routine interactions between different projects, we relate the generative potential to whether the actants connecting routines become mediators or intermediaries. In other words, we look at what effects actants can have on important organizational processes through their engagement. Our results advance the understanding of the relationship between organizational routines and innovation, suggesting that approaching routine interaction from a performative perspective might help in resolving the paradox between doing a routine task and performing routines to generate novelty. Similar to the conception of organizational routines as dynamic and generative systems, the ongoing interaction between routines mediated by the connecting actants can be more or less generative.

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Endnotes

[1]See https://www.youtube.com/watch?v=2nHWtBLDxDs.

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