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Managing the Repertoire: Stories, Metaphors, Prototypes, and Concept Coherence in Product Innovation

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A recognized challenge in innovation scholarship is how to coordinate the efforts of many minds contributing to the design of a single artifact. Much research shows that product concept representations can help coordinate design tasks, but we know little about the practices that make representations more or less effective. We used an inductive approach to examine how six teams in three industries used concept representations when creating novel products. All six teams crafted three types of representations: stories, metaphors, and prototypes. However, merely using representations did not ensure a shared repertoire and concept coherence—a common understanding of desired product attributes. Teams that failed to consistently engage in three practices—(1) collective scrutiny of representations, (2) linking representations to design constraints, and (3) active editing of representations—produced concept disunity, with disparate understandings of desired product attributes. Teams that maintained concept coherence were better able to coordinate design tasks than teams that experienced concept disunity. Our research explains how the ultimate effect of concept representations on the coordination of innovation is contingent on the practices used to manage a repertoire of representations in use.

Keywords: coordination; innovation; design; representation; boundary object; product concept
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Introduction

A recognized challenge in innovation scholarship is how to coordinate the efforts of many minds contributing to the design of a single artifact (Dougherty 1992, Brooks 1995, Brown and Eisenhardt 1995). The challenge of coordinating specialized design tasks has been of interest in many innovation contexts, including automotive design (Clark and Fujimoto 1991), architecture (Alexander 1964), and software engineering (Brooks 1995). Research on the coordination of interdependent work has traditionally focused on formal mechanisms of control, such as the design of work tasks or organizational structures. More recently, theorists have developed a deeper appreciation of the dynamic practices that enable individuals to align their efforts in the moment (Okhuysen and Bechky 2009), especially when developing new innovations (Bartel and Garud 2009, Dougherty 2001). Rather than assume that procedures, plans, rules, and schedules foster the integration of differentiated tasks (e.g., Lawrence and Lorsch 1967), scholars are increasingly interested in a broad range of mechanisms such as routines (Feldman and Pentland 2003), boundary objects (Bechky 2003a, b; Carlile 2002), roles (Bechky 2006), practices (Kellogg et al. 2006), and frames (Kaplan 2008, Kaplan and Tripsas 2008) that allow individuals to specialize on defined tasks while contributing to interdependent goals in ways that may be difficult to specify in advance.

These coordination mechanisms are more fluid than traditional structures, and their success can be affected by representations of a collective effort. What Simon (1996) termed "appropriate representations" help orient individuals around a common effort that may lack precise definition. For example, Schön (1993) described how a team member collaborating on the design of a new synthetic-bristle paintbrush observed that, "you know, a paintbrush is a kind of pump!" (p. 140) with paint flowing between the bristles. The pump metaphor served as a representation that helped the team refocus its attention from the paintbrush bristles to the spaces between them, shifting design efforts in a novel way. As Okhuysen and Bechky (2009) summarized in their integrative study of coordination research, "Objects and representations therefore coordinate by providing information. They also offer a common referent around which people interact, align their work, and create shared meaning" (p. 474). Representations help individuals process complex information and direct their attention, which is especially important when information is ambiguous, changing, or conflicting (Ocasio 1997, Walsh 1995), as is the case when teams are creating novel products. The ability to represent novel concepts to all involved is critical to developing a common understanding and directing individual efforts in a manner that permits their eventual integration (Leonardi 2011, Okhuysen and Bechky 2009).

Although scholars agree that concept representations can be important in coordinating design tasks, two literatures have adopted different approaches to studying them, with little exchange between them. The first approach primarily examines how leaders use linguistic representations—such as stories or metaphors—to coordinate organization-wide initiatives. For example, metaphors selectively frame information to guide individual interpretation of events (Goffman 1974), direct attention (Ocasio 1997), and align individual efforts within a collective (Snow et al. 1986). Research has shown how leaders in organizations frame strategic problems and solutions to shape change (Kaplan 2008, Tripsas and Gavetti 2000), gain political advantage (Boje 1991), achieve legitimacy (Zott and Huy 2007), or acquire resources (Martens et al. 2007).

The second approach examines how people use material representations, such as prototypes, to coordinate across specialized knowledge domains during the innovation process. Research in this tradition has focused on how individuals resolve coordination problems using artifacts as boundary objects (Bechky 2003a, Carlile 2002). This research shows how those undertaking interdependent work use representations to resolve coordination challenges across occupational boundaries (Bechky 2003b, Star and Griesemer 1989) or knowledge barriers (Carlile 2002, Nicolini et al. 2012). These two research streams have evolved independently, but they both help explain how individuals solve coordination problems without formal coordination structures. Yet two limitations provide an opportunity for a broader investigation of the role of representations in coordinating innovative work.

First, prior research tends to focus on one representation at a time, which may mask effects where both linguistic and material representations are used within organizations, such as during the design of new products (Hargadon and Sutton 1997, Stigliani and Ravasi 2012). Second, much prior research focuses on the promise of representations without specifying the conditions that make them more or less effective. Representations can create misunderstandings as well as resolve them (Nicolini et al. 2012). Nicolini et al. (2012) warned that boundary objects can become a "catch-all notion" (p. 614) and that "in short, when all objects become boundary objects, the explanatory power of the theory is undermined" (p. 613). If we are to understand how concept representations affect the coordination of design tasks distributed among many individuals, then we need a research focus that is agnostic to the types of representations in use. Otherwise, we risk developing theories specific to types of representations rather than to the broader challenge of coordinating innovation.

Thus, we examined a process at the juncture of team- and organizational-level initiatives: the development of novel concepts into innovative products. Teams engaged in such efforts confront much ambiguity as to how attributes from existing categories should be recombined (Clark 1985, Rosa et al. 1999). Our research explored how teams used both linguistic and material representations in coordinating design tasks and the practices that made representations more or less effective.

We examined how six product development teams in three different industries used concept representations to coordinate their efforts. All teams crafted three types of concept representations—stories, metaphors, and prototypes—but merely using these representations was not enough to gain a common understanding and coordinate design tasks effectively. On three teams, multiple representations, left unmanaged, resulted in *concept disunity*, where team members maintained disparate understandings of desired product attributes. Three other teams avoided this outcome by consistently using coordinating practices with their representations to produce *concept coherence*, where team members established a common repertoire of representations and a common understanding of desired product attributes. Teams that achieved concept coherence were better able to coordinate design tasks than teams that experienced concept disunity. Prior research suggests that common understanding is necessary to coordinate interdependent tasks (Okhuysen and Bechky 2009) but typically does not appreciate how concept representations can also hamper coordination. Our research shows that the effect of concept representations on the coordination of design tasks depends on the practices used to define and manage a repertoire of representations. When unmanaged, a plurality of representations can do more harm than good.

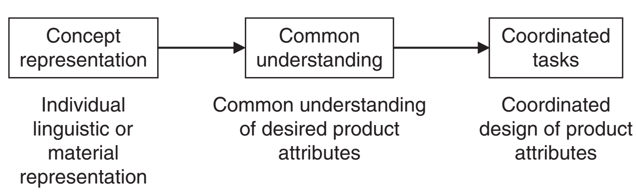
Innovation and Concept Representations

Traditional approaches to product development involve gathering customer requirements, considering competitors, and establishing criteria to inform the product attributes to be developed (Bacon et al. 1994, Brown and Eisenhardt 1995). When creating incremental innovations, product concepts can be clearly specified with this method, and teams can coordinate individual design tasks by drawing on well-established routines. When creating novel products, teams face considerable ambiguity about the nature of design tasks, as the process is inherently uncertain and dynamic (O'Connor and Rice 2013, Van de Ven et al. 2008). This can make it difficult to coordinate collective efforts as the outcome cannot be specified a priori (Weick 1990). Even with a description of the innovation challenge, team members may interpret their tasks differently, compounding the challenge of developing an integrated outcome (Dougherty 1992). Formal structures such as team composition and well-trained project leaders can address some of these challenges (Brown and Eisenhardt 1995, Katz and Allen 1985), but concept representations also help parties develop a common understanding of the task and orient them toward an agreed-upon outcome (Clark and Fujimoto 1991, Okhuysen and Bechky 2009). For example, Jarzabkowski et al. (2012) showed how people restructuring a service product were affected by the sudden absence of a coordination representation long relied on. To avoid disruption, team members developed new tools to make interdependent tasks more visible to all involved.

Prior research suggests that teams that create an easily communicated representation of their product concept are able to coordinate their efforts better than teams that do not use representations. For example, Clark and Fujimoto (1991) described how the metaphor of a "pocket rocket" could represent a small, lightweight, and speedy car that would help team members coordinate design decisions, resulting in better alignment among attributes of the car they were developing. Prior research shows how product concept *specifications* are developed (Bacon et al. 1994, Brown and Eisenhardt 1995) and revised as new information becomes available (Lynn et al. 1996), But we know less about how *representations* of the product concept—such as the pocket rocket metaphor—are generated, communicated, and revised. Though both academics (Clark and Fujimoto 1991, Schön 1993) and practitioners (Kelley 2001, Schrage 1999) have argued that the use of a concept representation may facilitate the coordination of design tasks, these accounts have primarily focused on the potential benefits of using a representation, not on the practices that may drive variance in outcomes.

A large body of prior research suggests that concept representations enable individual interpretations of work tasks to align with collective outcomes (Okhuysen and Bechky 2009), leading to the basic model outlined in Figure 1. As applied to innovation, this model describes how an individual representation will promote a common understanding of desired product attributes, which in turn will enhance the coordination of design tasks (Clark and Fujimoto 1991, Schön 1993, Simon 1996). However, we do not know how representations enable or inhibit coordination when multiple types of concept representations are present. Several points of tangency in the literatures examining linguistic and material concept representations motivate our approach.

Figure 1 **Basic Model of Individual Representation, Common Understanding, and Coordination as Applied to Product Innovation**



Linguistic Representations

Linguistic representations are verbal or written means used to communicate a concept to guide individual and collective action. Although there are many types, stories and metaphors are most relevant in an innovation context (e.g., Bartel and Garud 2009, Dahl and Moreau 2002, Schön 1993). Research on linguistic representations derives from insight into individual-level processes. Metaphorical language is pervasive in human thought (Ortony 1993), and metaphorical expressions foster creative thinking at the individual level (Dahl and Moreau 2002, Schön 1993). In organizational settings, executives, leaders, and entrepreneurs use linguistic representations to acquire legitimacy or resources (Lounsbury and Glynn 2001, Zott and Huy 2007), achieve organizational change (Kaplan 2008), or facilitate institutional change (Etzion and Ferraro 2010). For example, Lounsbury and Glynn (2001) showed how entrepreneurs used stories to gain legitimacy for their ventures to improve their chances of funding.

Metaphors and stories represent concepts in slightly different ways. Metaphors efficiently direct individuals' attention by facilitating the transfer of relations from one domain to another (Ocasio 1997). Entrepreneurs who promote adoption of their novel innovations by making analogies to existing institutions are particularly effective at having their initiative adopted (Etzion and Ferraro 2010, Hargadon and Douglas 2001). When introducing the electric light, Edison carefully invoked the familiarity of gas lighting to gain acceptance from existing institutions: "Edison triumphed over the gas industry not by clearly distinguishing his new system from but, rather, by initially cloaking it in the mantle of these established institutions" (Hargadon and Douglas 2001, p. 479). Similarly, Etzion and Ferraro (2010) showed how institutional entrepreneurs in the Global Reporting Initiative drew on well-known financial standards to gain acceptance for new sustainability guidelines.

Metaphors not only direct individuals' attention, they also provide a vivid means to stimulate action. Ortony (1975, p. 51) noted that "the vivid imagery arising from metaphorical comprehension encourages memorability and generates of necessity a better, more insightful, personal understanding." Metaphorical teaching strategies allow new concepts to be learned more effectively than explicit, direct presentation of a concept's attributes (Petrie and Oshlag 1993). Such imagery also helps promote goals in managerial settings. By making the unfamiliar familiar, metaphorical language can foster the appreciation of new technology and inform peoples' understanding of its attributes. For example, in framing camera memory cards as "digital film," the firm Linco evoked the metaphor of film rather than electronic memory to influence how people perceived the new digital product (Tripsas 2009).

Like metaphors, stories help narrow ambiguity in equivocal situations in a memorable manner (Boje 1991). Unlike metaphors, stories provide a narrative that unfolds over time, which allows for a more complicated set of relationships to develop (Martens et al. 2007). Narratives are marked by a subject in search of an object and forces aiding or hindering the subject in acquiring that object (Fiol 1989). Martens et al. (2007) showed how entrepreneurs who used a variety of storytelling strategies were more successful at fund-raising, in part due to the rich material they succinctly conveyed. Stories may be more fluid than metaphoric language. Shared narratives about problematic photocopiers traded among photocopy repair personnel evolved as actors and machines changed, helping technicians solve problems in ways that the static knowledge provided by repair manuals was unable to address (Orr 1996).

Both metaphors and stories can be vivid, direct attention, and facilitate or constrain action (Sillince et al. 2012). These types of representations are efficient, in that they are concise, repeatable, and spread among organization members with minimal effort (Heath and Heath 2007, Ortony 1993). However, the same properties that make linguistic representations compelling can lead to inertia and resistance once in place (Petrie and Oshlag 1993). If linguistic representations are "sticky" (Heath and Heath 2007), they may impede the organization from adapting to a changing environment, with serious consequences. Tripsas and Gavetti (2000) showed how metaphors related to a film-based business model prevented Polaroid leaders from shifting to digital photography even though the firm had extensive digital capabilities. Yet little research has examined how individuals throughout an organization receive and act on linguistic representations and how representations evolve in use.

Material Representations

An alternative approach has examined how individuals draw on material representations to translate knowledge from one domain to another to resolve coordination challenges (Bechky 2003a; Carlile 2002, 2004; Ewenstein and Whyte 2009; Nicolini et al. 2012). Most definitions consider material representations to be physical objects used to communicate a concept to inform individual work that must be integrated with a collective. Prototypes and boundary objects are commonly studied. For example, in Bechky's (2003a) study of a semiconductor manufacturer, engineering drawings and prototypes helped solve problems that crossed the expertise boundaries of engineers, technicians, and assemblers. Bechky showed how the three groups maintained divergent conceptualizations of the product they would build and how, through the use of material representations, these differences were resolved. Boundary objects, in this regard, offer a common umbrella under which divergent understandings can be reconciled (Star and Griesemer 1989).

Similarly, Carlile (2002) examined how workers in sales, design engineering, manufacturing engineering, and production functions maintained disparate understandings. Only when material representations translated across these four functions were they able to serve as effective boundary objects, enabling differences in understanding to be transformed into a common understanding. These studies brought attention to boundary objects as an underappreciated but potentially transformative way to explain how experts from different disciplines could coordinate their work despite disparate thought worlds (Dougherty 1992). Carlile (2002) argued that an effective boundary object provides "a concrete means for individuals to specify and learn about their differences and dependencies across a given boundary" (p. 452). Their adaptability enables people working on innovation challenges to understand where interpretations differ and create the common ground needed to identify solutions to coordination challenges that cannot be specified in advance (Okhuysen and Bechky 2009). The presence of a prototype, even in a simplified form, can elicit a more nuanced understanding of product attributes and unmet needs than a verbal depiction alone, facilitating future iterations of design (Henderson 1995, Stigliani and Ravasi 2012).

Whereas scholars in this tradition originally focused on material objects, what constitutes a "boundary object" has expanded (Zeiss and Groenewegen 2009). For example, architect Frank Gehry's design firm used three-dimensional representations "as a medium for communication and coordination with contractors, engineers, builders, and fabricators" (Boland et al. 2007, p. 644) to foster the coordination of work as well as the strategic direction of design efforts. Bartel and Garud (2009) suggested that narratives can be considered boundary objects when they help actors resolve coordination challenges. The problem is that much of this research focuses on the promise of boundary objects without specifying the conditions that make them more or less effective. Although the range of what can be considered a boundary object has expanded, what is needed is an examination of the practices that enable any type of concept representation to be understood by different parties and how representations affect coordination—for better or for worse.

Repertoires of Representations

Both linguistic and material representations help individuals develop a common understanding of concepts needed to facilitate the coordination of design tasks. Yet scholars have tended to research a specific type of representation—such as metaphors or boundary objects—in isolation, rather than explore how a repertoire of representations affects coordination. When concept representations are examined individually, we fail to appreciate the full range of representations in use, the different types of information they offer, what can result from their use in concert, and how potentially competing information is or is not resolved. A focus on a particular frame or object may narrow our understanding of how people draw from a plurality of meanings to accomplish common understanding. For example, engineers at design firms frequently draw on prototypes as well as metaphors to collectively produce novel innovations (Hargadon and Sutton 1997, Stigliani and Ravasi 2012). In Bechky's study of semiconductor chip design (Bechky 2003a), engineers preferred to work with drawings while technicians preferred to work with prototypes; this had consequences for the coordination of interdependent work.

Furthermore, the use of concept representations affects individuals throughout the organization working on an innovative task. Studies focused solely on product teams or solely on leaders may limit a dynamic theoretical understanding of how concept representations are used, challenged, and revised by all parties. What is less understood is the social life of representations: how other members of the organization receive and absorb linguistic and material representations throughout the innovation process. We know little about the practices or conditions that make representations more or less effective in coordinating the many tasks needed to execute an innovative vision. The reality is likely to be not only more nuanced but also more interesting if we consider how all organizational members draw from a repertoire of representations (e.g., Clark and Staunton 1989, Clemens 1993, Swidler 1986, Tilly 1993). A repertoire is merely a collection of practices held in common (Kellogg 2011, Leonardi 2011) from which individuals select responses to particular situations (Clark and Staunton 1989). Repertoires define and bound the range of a community's practices (Orlikowski and Yates 1994). When individuals share a common repertoire for interpreting and responding to particular situations, they can achieve consensus on a course of action even when their background or training is quite different (Clemens 1993, p. 759). Thus repertoires are one way to resolve differences in interpretation: they bound the set of solutions from which empowered individuals can draw to address organizing challenges.

Rather than appreciate how a repertoire of multiple representations might affect coordination, the focus has been on how people select one "best" representation. We know little about how different forms of concept representations are selected, revised, and managed by all who contribute to novel innovations (Brown and Eisenhardt 1995, Shane and Ulrich 2004) and how this contributes to or inhibits coordination. The promise of representations is well known, but their limitations are less examined. Our research addresses these questions by examining how teams used both linguistic and material representations to coordinate the development of novel products and the practices that enabled representations to be more or less effective.

Methods

Case studies are an effective mode of inquiry for exploring research questions affected by organizational context (Yin 1994), especially when the factors that may be relevant to outcomes are not yet known (Eisenhardt 1989). As part of a broader study, we initially formed case studies of teams that recently launched products novel to both the organization and the market, but where market outcomes were not yet certain. A first study found that product concepts and representations changed during the process of creating radical, category-defying products (Seidel 2007). The present study examined the practices by which concept representations were used more or less effectively.

Initial interviews indicated whether a project was considered novel within the organization. Press accounts from outlets such as the *New York Times* or the *Wall Street Journal* provided external assessments of novelty. Initially, eight projects were identified, but after this assessment, two projects were considered incremental innovation and were not included in this research. Table 1 presents descriptive information of the six cases selected and shows how each team's product concept was novel both to the organization and to the market.

To preserve confidentiality, project names were disguised and a case name chosen to indicate the project's focus. Some descriptions of product concepts were slightly altered to ensure that informants remained unidentifiable while preserving enough detail to illustrate representations and practices.

To develop theory that could be generalizable across contexts, we selected projects from three different industries (consumer electronics, medical/sports therapy devices, and automotive). This provided variance in development cycles that might affect the creation of novel products. Whereas consumer electronics projects have short development cycles, automotive product development cycles can run for more than four years, and medical/sports therapy devices have lengthy regulatory reviews. From the consumer electronics industry, we selected two projects from similarly sized firms: "eBook" and "PDAPhone." The eBook team developed one of the first handheld electronic book readers, helping define a new category of such readers. The PDAPhone team developed one of the first products to integrate personal digital assistant (PDA), mobile phone, and email functions. From the automotive industry, we selected two projects, "RadCross" and "FlexTruck," from two divisions of the same firm. The RadCross team created the

Table 1 Description of Cases and Evidence of Novelty

Project name and description	Firm size and location	Core team size	Evidence of novelty to market	Evidence of novelty to organization
eBook: Handheld electronic book reader	Medium (∼100) California	∼30	—Press: A *New York Times* article asks, "Is this the end for books?" —Awards: Two major design innovation awards	"[W]e were making something that had never been made before, so it was hard to ask customers whether it suited their needs, because they had never seen one before."—eBook executive leader
PDAPhone: "Smartphone" mobile device	Medium (∼300) California	∼20	—Example press: Positive reviews in the *New York Times* citing it as one of first in the category —Awards: Major annual design innovation award	"[The emerging market] is defined as a combination of voice, data, and PDA. The platform together is just being defined...."—PDAPhone engineering manager
RadCross: "Crossover" of car and truck	Large (> 1,000) Michigan	∼35	—Example press: A *New York Times* review describes it as a new niche —Awards: Award for interior design, comfort, and convenience features	"It was a brand-new type of vehicle that we had never done before, being this 'crossover' type of vehicle...."—RadCross (premium version) product designer
FlexTruck: Truck with flexible cargo area	Large (> 1,000) Michigan	∼20	—Example press: A *New York Times* article notes the "clever idea" central to the concept —Awards: Two major automotive magazine awards including one for "design and engineering"	Described as "a very unique concept."—FlexTruck engineering manager
BodyCool: Body cooling device with new method	Small (8) California	6	—Example press: A *New York Times* article noted it as a new cooling system —Awards: Award by medical charity for "outstanding design innovation"	"[W]hen you are dealing with a revolutionary device, the customer itself doesn't know what they [*sic*] want."—BodyCool quality manager
JointCool: Cooling device combining two therapies	Small (9) California	6	—Example press: *Wall Street Journal* covers the novelty of the approach and space science background —Awards: Brand agency award and testimonials from diverse national sports professionals	"People [who first try it] are like, 'Wow, it's different.' This is what we were trying to connote [with the design] is: this is something new; this is not something that you've used before."—JointCool engineering manager

firm's first "crossover" vehicle, incorporating a mix of product attributes not previously available. The FlexTruck team created a truck with a novel flexible cargo area. From the medical/sports therapy industry, we identified two similarly sized firms with teams producing novel products: "BodyCool" and "JointCool." The BodyCool team developed body cooling based on technology targeted for serious medical applications for overheated patients. The JointCool team designed a novel combination of therapies to cool joints following an injury. The consumer electronic and medical/sports therapy teams were both from privately held small-to-medium-sized firms located in California, and both automotive teams were from a large public firm in Michigan.

Data Collection

Because we selected cases that shared a common outcome, our focus was on the practices product development teams used across cases. The first author began data collection in the summer of 2001, shortly after teams had launched their products, with field work continuing for 18 months. Since all product launches were relatively recent, teams were still active in product development, and much of the data were readily available. Our approach was to conduct as many in-person interviews as possible and to take advantage of project data maintained by each team. Project data included written and visual descriptions of each team's product concept and key milestones for each project.

As Table 2 shows, the first author conducted 51 interviews in conjunction with over a dozen site visits across six teams. The first author gathered field data from each site, visiting each California site at least twice and observing the RadCross and FlexTruck teams for three months. On site visits, which were full days at the automotive company and half days at other firms, we observed how teams communicated their novel product concepts in various forms. For example, at the RadCross and FlexTruck sites, we had access to team meeting rooms featuring illustrations and models of different

Table 2 Overview of Field Data Collected

	Consumer electronics industry		Automotive industry		Medical and sports therapy industry	
	eBook	PDAPhone	RadCross	FlexTruck	BodyCool	JointCool
Project leaders interviewed	Executive sponsor Project leader	Executive sponsor Project leader	Executive sponsor Project leader	Executive sponsor Project leader	Executive sponsor Project leader	Executive sponsor Project leader
Other members interviewed	Engineering manager Marketing manager Software manager Engineers and product designers (3)	Engineering manager Marketing manager Engineer	Engineering manager Marketing manager Product designers (2) Engineers and other technical staff (9)	Engineering manager Marketing manager Engineers and product designers (5)	Engineering manager Marketing manager Quality manager Engineer	Engineering managers (2, one incoming and one outgoing) Marketing manager Staff (1) and contract (2) engineers/ designers
Interviews (total = 51)	8	5	15	9	6	8
Archival data	Internal reports, internal concept screen shots, industry reports, site visits	Archival interviews, industry reports, site visits	Internal reports, internal concept drawings, industry reports, two months on-site	Internal reports, internal concept drawings, industry reports, two months on-site	Internal reports, internal concept drawings, industry reports, site visits	Internal reports, internal concept drawings, industry reports, site visits

vehicle concepts. At the JointCool site, we observed many different prototypes designed for the product as the concept evolved. In site visits with the PDAPhone team, different prototypes were on display that reflected the evolution of their product concept.

We interviewed informants in at least five different roles: (1) an executive leader (the chief executive officer of smaller firms or executive champion in larger firms), (2) a project leader (responsible for project coordination), (3) engineering manager (responsible for a team of engineers), (4) marketing manager, and (5) engineer or product designer (preferably both). Interview questions focused on the practices used to communicate and coordinate product concepts from inception to launch. All interviews were audiotaped when permitted, which included all but three informants. Interviews were transcribed, with a total of 10,276 paragraphs of interview dialogue. Interviews and data from site visits were supplemented with publicly available materials.

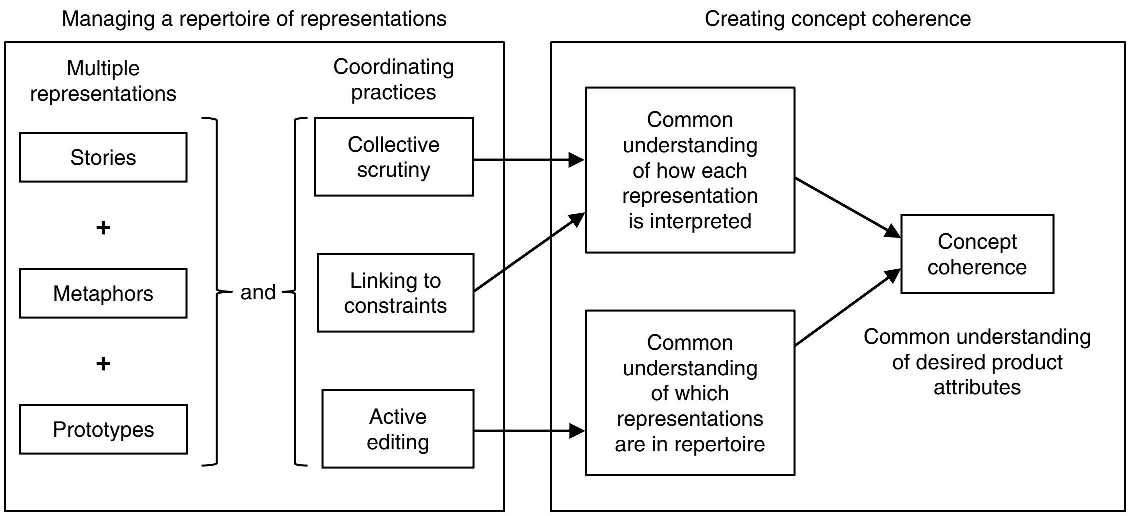
Data Analysis

Data analysis was a four-phase process. In the first phase, we wrote comprehensive summaries of each case, detailing the practices and concept representations used by each team. We found that each team relied on several different types of representations to communicate different aspects of their product concept. In the second phase, we coded our data to determine the range of representations used. Beyond preliminary drawings and notes, we identified three types of representations that all six teams used to coordinate product design and development: (1) stories, (2) metaphors, and (3) prototypes. In the third phase, we discovered that not all of these teams benefited equally from the use of concept representations. Thus, we recoded our data to identify the practices that led some teams to be more successful at coordinating their innovative efforts than other teams.

We identified three distinct coordinating practices that teams used to a varying degree of consistency: (1) collective scrutiny of representations, (2) linking representations to design constraints, and (3) active editing among a repertoire of representations. Teams that consistently used all three coordinating practices achieved concept coherence—a common understanding of desired product attributes. Teams that did not consistently use all three coordination practices experienced concept disunity, where disparate understandings of desired product attributes persisted. We revisited theory and data to understand why these three coordination practices were critical to the effective use of concept representations. Teams that maintained concept coherence were better able to coordinate design tasks than teams that experienced concept disunity. From this analysis, we developed a grounded theoretical explanation of how a plurality of concept representations can either enhance or inhibit concept coherence and the coordination of innovation.

We introduce our findings with the elaborated model of managing a repetoire of representations illustrated in Figure 2. When multiple concept representations were used with the three coordinating practices, teams produced two modes of common understanding: common understanding of how each representation was to be

Figure 2 Elaborated Model: Managing a Repertoire of Representations for Concept Coherence



interpreted and common understanding of which representations were in a shared repertoire. These two modes of common understanding created concept coherence: a common understanding of desired product attributes. As established by prior research, common understanding of desired attributes is critical in fostering coordination. Our model elaborates the basic model presented in Figure 1 by addressing multiple representations, by isolating two modes of common understanding, and by articulating the necessary practices by which representations foster concept coherence.

Concept Representations and Coordinating Practices

Novel concepts presented teams with two main challenges: (1) how to recombine attributes of existing concepts to create something novel and (2) how to specify product attributes when they were not identifiable a priori but unfolding as teams experimented with what was possible. Both challenges created ambiguity, as team members could plausibly maintain competing interpretations of the novel concept. As the eBook marketing manager explained, "We're really trying to create a new category here, and that is a really tough thing to do."

For example, the RadCross team was trying to recombine car and sport utility vehicle (SUV) truck concepts, but what this meant in practice was not clear to all team members. One engineer found it difficult to know whether to design the fuel tank with "car-like" or "truck-like" attributes. Trucks need to prevent water intrusion into the fuel tank, whereas cars do not, and this difference implied very distinct fuel tank designs. As the engineer explained, "I remember with the water intrusion testing, we actually went to the platform [engineers]...it was kind of like, 'We really want this to be like an off-road truck.' But at the same time, they come back and tell you, 'Now it's going to be more like a van.' " Table 3

Table 3 Ambiguity of a Design Task for Each Novel Concept

Case	Novel concept	Related existing concepts	Example ambiguity of design tasks
eBook	Electronic book reader	Physical books, electronic displays	Electronic displays provide the ability to scroll through text, but books have page turns. How should text be navigated in an electronic book?
PDAPhone	Smartphone	Personal digital assistant, mobile phone	A personal digital assistant requires a large area for entering text, but many successful phones try to minimize area and buttons. What form should be used?
RadCross	Crossover vehicle	Sports car, SUV	A sports car has a low ride height but an SUV has a high ride height. What is an appropriate ride height for a crossover?
FlexTruck	Flexible pickup truck	Pickup truck, SUV	If vehicle is to function as a pickup truck it must have an open cargo bed, but a sport utility vehicle keeps items secure. How can both features be combined?
BodyCool	Whole-body cooling device	Ice bath, climate control like a space suit	The new device could be complex and fragile but may need to be used in rugged environments. What design provides enough protection yet allows portability?
JointCool	Cooling device with compression	Ice pack, compression bandages	When combining cooling and compression, a refrigeration system provides more flexibility than ice but complicates a compression system. What cooling process should the device use?

shows that all six teams faced similar sources of ambiguity. Although all teams initiated their projects with loose agreement on the goal they wanted to achieve, such as a new crossover vehicle, they all faced many questions as to what the final product's form would be and the specific attributes it would include.

The second challenge was that all of a product concept's attributes were not known at the outset but discovered as product development unfolded. For example, the JointCool team knew the science behind a novel concept to reduce swelling caused by injuries, but the means by which the device would be powered and how it would be transported were still to be determined. The lead engineer could not ask potential customers what attributes they preferred in a new cooling therapeutic product that did not yet exist. His challenge was to translate the concept into product attributes without this information. We found that all six teams crafted multiple types of concept representations to communicate different aspects of their product concept throughout the team.

Crafting Concept Representations

To convey the attributes their product would include, all six teams crafted at least three types of concept representations: (1) stories, (2) metaphors, and (3) physical prototypes. Teams primarily used stories to explain customer needs, metaphors to articulate product functions, and prototypes to define a product's form, though a representation could often convey attributes that applied across form and function. Examples of the three types of concept representations crafted by the six teams are provided in Table 4.

Stories. All product teams used a story about how the novel concept originated. These stories featured a protagonist faced with a challenge that the product could help solve. Storytelling in organizations has been found to guide identity and a sense of purpose for participants (Martin 1982) and to explain how to get work done (Orr 1996). In our research, stories primarily conveyed unmet customer needs that motivated the opportunity for a new product and oriented teams around possible solutions. In the case of eBook, a story of the founder needing to access a large volume of reading material on an international flight became widely shared among the team. As one eBook designer recalled, "The original problem I heard [the executive manager describe was that] on an airplane, you have a ton of paperwork, or a ton of books that you would like to get through, why couldn't you…just download what you wanted in one place?" This story was repeated by others and used to inform specific product attributes; for example, the product's battery life and product size both needed to be conducive

Table 4 Examples of Concept Representations Crafted by Each Team

	Story	Metaphor	Prototype
eBook			
Handheld electronic book reader	Story of executive leader running out of reading material on flight from San Francisco to Hong Kong	"It's not a computer, it's a book!" and "Pages, not K-bytes" metaphors to describe memory in book-like terms	"To introduce [engineers to the project]…we showed them a model…."—Executive manager
PDAPhone			
Smartphone mobile device	Story of failure of a past project to meet perceived need	"No trade-offs!" was metaphorically used to describe adding full phone capability to PDA and email	"You build a model. It gets carried around, it gets talked about, it gets refined."—Lead engineer
RadCross			
Crossover of car and truck	Story of how they found customer needs were changing to enable this new crossover	The crossover was to be "a sports car and an SUV in a blender"	"You cannot beat a full-size [prototype] for generating excitement around a concept."—Planning manager
FlexTruck			
Truck with flexible cargo area	A story of a naive customer assuming such flexibility was possible	To convey flexibility, "Swiss Army knife" was used among team	"[T]hey had a theme model…people were coming to see it. There was a lot of good momentum."—Designer
BodyCool			
Body cooling device with new method	Story of founder reading a scientific paper and having daughter do a school science project to test the concept	Metaphor that we will "trick the body" into cooling itself used among staff	"[The rough mock-up heating pad] was actually very compelling."—Design engineer
JointCool			
Cooling device combining two therapies	Story of how the technology was used in space applications and could be applied to therapy	Was combining "an ice pack and an Ace bandage"	"I was able to look at the product [prototype], and touch it, and hold it, and see how it was put together."—Designer

to air travel. This story was very memorable or "sticky" (Heath and Heath 2007), even after the intended use for the electronic book changed later in development. The FlexTruck team focused on a story of a customer who thought that there was a flexible feature on a pickup truck bed that did not actually exist. The story was repeated among many team members and summarized in a memo: "Big idea: In focus groups, some respondents inquired whether [there could be flexible access to cargo]. Combined with the possibility of an [electrical solution] this idea generated a great deal of enthusiasm among several groups and ... the concept [was] born." Stories about unmet consumer cargo needs helped corral commitment and understanding in an ambiguous and potentially risky project.

Metaphors. Whereas stories were used primarily to communicate consumer needs, all six teams used metaphors to represent desired product attributes. On the JointCool project, team members described the product metaphorically as a high-tech replacement for "an ice pack and an Ace bandage," combining cold and compression therapies. Grounding the product in this metaphor emphasized the simplicity the team was looking for, in a means that combined attributes in a new way. The FlexTruck team used a metaphor of a "transformer" toy that transformed from a robot into a vehicle. Transformer toys were visible on many desks as a humorous representation of the goal for a completely convertible loading area. RadCross also used metaphors, and a planning analyst explained, "In generating metaphors, we were trying to come up with clear ways to explain a product that did not exist ... to make it easy to understand for folks." Early on, the team created a metaphor that the vehicle would be "a sports car and an SUV in a blender." However, unlike the FlexTruck team, this metaphor was misremembered and became convoluted and interpreted differently by team members, which generated disparate understandings of the product's attributes.

Prototypes. All six teams also used prototypes. Even very rough prototypes helped team members create a common understanding of product form and function. The executive of the firm designing the PDAPhone used a crude wooden mock-up of the product, and the engineering manager summarized how it drove design tasks: "You build a model. It gets carried around, it gets talked about, it gets refined." When the PDA form changed dramatically midway through the project, the prototypes in use were changed to align with the new product's shape. The FlexTruck team had a prototype that communicated the "basic vision of what this truck needed to be, absolutely the most unique, best vehicle we could build, the most creative, the most functional truck we could build." Even though the "model didn't have all [the eventual solutions] ...," it created "good buzz." Iterating through design options with multiple prototypes generated interest in the project and helped to not only recruit people to work on a project initially viewed as high risk but also enabled the team to get critical early feedback. However, prototypes created by the RadCross team were developed for a "show car" event and deviated substantially from the evolving product concept, generating disparate understandings of desired product attributes within the team. Thus, crafting concept representations did not always help teams coordinate their interdependent work. In some cases, a proliferation of competing concept representations actually fostered misunderstandings.

A Plurality of Representations. Prior research has recognized that concept representations are critical to enabling people to move from the conceptual realm to put new ideas into practice (Hargadon and Douglas 2001, Lounsbury and Glynn 2001, Ortony 1993). Consistent with this expectation, all six teams used concept representations to communicate different aspects of their product concepts to their teams. This was robust across settings which varied by industry, location, and firm size. Why were the prototypes used by the FlexTruck team effective at creating a common understanding while the prototypes used by the RadCross team generated misunderstandings? Why were stories used to great success by the FlexTruck team and metaphors misremembered on the RadCross team? A plurality of representations fostered a common understanding of desired product attributes on teams that created *concept coherence*, but other teams were plagued with confusion and disparate interpretations of what they were creating, experiencing *concept disunity*. After defining these two constructs in more detail, we show how specific coordinating practices used in conjunction with multiple representations affected whether representations aided or impeded concept coherence and the coordination of design tasks.

Concept Coherence vs. Concept Disunity

We define concept coherence as a team-level construct indicating the degree to which team members create and maintain a common understanding of desired product attributes. To achieve concept coherence, teams had to (1) share a common interpretation of representations and (2) maintain a common repertoire of representations. Product integrity refers to the alignment among attributes of a completed product (Clark and Fujimoto 1991), and concept coherence refers to the degree to which team members "stay on the same page" regarding desired attributes as the product concept evolves. In his landmark study of complex development projects, Frederick Brooks observed the challenge that "any product that is sufficiently big or urgent to require the effort of many minds thus encounters a peculiar difficulty:

the result must be conceptually coherent to the single mind of the user and at the same time designed by many minds. How does one organize design efforts so as to achieve conceptual integrity?" (Brooks 1995, p. 256). Whereas Clark and Fujimoto focused on product integrity, Brooks's definition of conceptual integrity considers how a product concept must first exist in the minds of many individuals during its development. Inspired by Brooks, our notion of concept coherence focuses not on the finished product but on the degree to which team members share a common understanding of desired product attributes *while* coordinating their design tasks. At the industry level, common understanding of a product's attributes would be considered a collective technological frame (Kaplan and Tripsas 2008) or a conceptual system (Rosa et al. 1999). At the team level, concept coherence focuses on how a new product's attributes are conceptualized before reaching the market.

Concept coherence only resulted when team members produced two modes of common understanding. The first mode of common understanding helped individuals ensure that their interpretation of a representation aligned with the rest of the team. Everyone on the FlexTruck team achieved the same understanding of how to interpret a Swiss Army knife metaphor. The second mode of common understanding established the boundaries of the repertoire of representations from which team members could draw upon to inform their design work. All members of the PDAPhone team knew when stick-shaped phone representations were pulled from the repertoire and replaced by flip phone representations. When teams achieved concept coherence, it did not mean that concept representations were stable and unchanging or that design incompatibilities were not confronted. Rather, team members' interpretations of how concept representations informed design tasks were updated in step as the product concept evolved and as barriers to implementation were overcome. By referencing a common repertoire of representations and interpreting them the same way, teams created concept coherence. These two modes of common understanding did not have to occur in a particular sequence.

Concept disunity reflected a lack of common understanding of desired product attributes. For example, on the RadCross team, members held disparate views of whether they were building "a sports car and an SUV in a blender" or "a sports car and a van in a blender." There was no agreement as to what representations were in the repertoire to inform the product's attributes and little agreement on how to interpret even those representations that were shared. A senior design analyst noted that "it became evident from probably the first meeting that there were already paradigms that were in conflict with the basic definition.... Right up front [others are] like, 'It's part minivan'...[but] it's not a minivan!" When both modes of common understanding were not achieved, teams exhibited concept disunity. In Brooks's (1995) terms, conceptual disunity "arises not from a serial succession of master designers, but from the separation of design into many tasks done by many men" (p. 42). Thus, concept disunity occurs not from hand-offs from one successive designer to another but from the challenge of seamlessly integrating the work of many individuals to appear as one. Teams exhibited concept disunity by either drawing on a plurality of representations not part of a shared repertoire or when team members maintained different interpretations of representations from a shared repertoire. Concept disunity was not movement away from a concept's original idea, as all product concepts experienced revision from the initial concept. Rather, concept disunity resulted when several individuals working on one concept began referencing disparate representations to inform their work. If all teams used multiple types of representations, why did some teams achieve concept coherence and others concept disunity? To address this question, we examined the practices teams used in conjunction with concept representations.

Coordinating Practices

Teams that achieved concept coherence consistently used three coordinating practices: (1) collective scrutiny of representations, (2) linking representations to design constraints, and (3) active editing among representations. Consistent use of all three practices helped team members question, absorb, and update concept representations in the same way even as the product evolved. Table 5 shows how the FlexTruck, PDAPhone, and JointCool teams maintained concept coherence.

Inconsistent use of these three practices led to concept disunity—where team members held disparate understandings of desired product attributes. These teams did not reference a common repertoire and could not agree on the set of concept representations that would inform their work, hampering their common understanding of product attributes and their coordination of interdependent design tasks. Table 6 shows how the RadCross, eBook, and BodyCool teams experienced concept disunity.

Next, we define each coordinating practice and show how each practice affected concept coherence or concept disunity. Teams that achieved concept coherence were able to coordinate design tasks in spite of design incompatibilities that emerged in the development process. Teams with concept disunity experienced coordination failures, delays, rework, or incompatibilities—some of which remained unresolved at product launch.

Collective Scrutiny of Concept Representations. Teams that engaged in collective scrutiny did two activities: (1) they shared all representations widely among the

Table 5 Use of Coordinating Practices by Teams with Concept Coherence

	Practice 1: Collective scrutiny of representations	Practice 2: Linking representations to design constraints	Practice 3: Active editing among representations	Evidence of concept coherence
FlexTruck	Consistency: HIGH Data sources: L, M, D "I think as a designer everybody was intrigued with this kind of convertibility…the Swiss Army knife idea of a truck." (Lead designer)	Consistency: HIGH Data sources: L, M, D "…[O]nce you got the basic concept there were tons of issues to execute to make it work. But you could see what was there was going to work…." (Lead engineer)	Consistency: HIGH Data sources: L, M, D When one representation no longer seemed to fit, there was active search for a new one: "Get 10 smart guys and lock yourself in a conference room [to come up with a solution]." (Executive manager)	Result: HIGH Data sources: L, M "At the end of the day the truck [concept] won. If someone had a better idea [of how to execute it] we shifted gears." (Lead engineer)
PDAPhone	Consistency: HIGH Data sources: L, M "Everyone knows what is going on…the team might grumble about [the idea] for a day and say, 'What are we doing?' …Then we come back and say, 'Okay, we're going to do this.'" (Project leader)	Consistency: HIGH Data sources: L, M, D "Almost every project there is I guess a couple of major, or semi-major resets. Usually they are when you are working down one way and all of a sudden there is something that does not make sense." (Executive manager)	Consistency: HIGH Data sources: L, M, D "The cofounder really controls the product definition, and when people try to put stuff in that doesn't go with his focus and definition, he's very good about killing it quickly, in a nice way." (Executive manager)	Result: HIGH Data sources: L, M Team noted following changes to the concept as it evolved, one recounted that "I think it helps to have a team understand where [the project leader's] vision is, and what he is working to." (Executive manager)
JointCool	Consistency: HIGH Data sources: L, M "I could look at the [prototype], touch it, hold it, and see how it was put together. [The marketing manager] did an excellent job explaining how [the founder] developed the technology…." (New designer)	Consistency: HIGH Data sources: L, M, D After learning about a new option, the team revised their "sacred cow" technology, realizing "it needlessly complicated the system." (Marketing manager)	Consistency: HIGH Data sources: L, M, D "There was basically a binder of product requirements. When [the new project manager] came on we reduced that to one page." (Engineer)	Result: HIGH Data sources: L, M Broad agreement on concept as it evolved, with willingness for possible additional changes to be left "on the back burner." (Lead engineer)

Note. L, leader interviews; M, member interviews; D, archival data.

team, and (2) they allowed all team members to question the scope and meaning those representations had for their product concept. Opening representations to questioning helped team members to resolve incompatible interpretations through discussion. For example, the FlexTruck team had a prototype in a secure location but made it available for viewing early in the project. This enabled project contributors from different functions to understand what the team was striving for and helped build support. As one engineer explained, "People would go, 'Have you seen that car they are working on?' There was a lot of good momentum." Representations were conveyed throughout the organization, sparking collective scrutiny of what the product concept would entail. One manager relayed that "[we] knew what the vision was; the small team that was there managing the program was united: 'This is what the truck is…we just have to figure out how to get there.'" Managers encouraged collective scrutiny of representations by organizing regular "town hall" meetings where people revised the product concept in real time: "We had a home, we had a place where everyone came together. Literally every two weeks we had a town hall meeting." These meetings were not progress check-ins but forums where the team could critically revisit the abstractions offered by their representations and engage in hands-on problem solving. As one engineer explained, "Lots of hands-on mock-ups, we had mock-up reviews at least once a week, all of management was there…as we worked through major issues…there were significant decisions made on a weekly basis."

Collective scrutiny gave team members the opportunity to share different interpretations of representations in use and question the applicability of these representations to individual design tasks. In this manner, differences of interpretation were aired and addressed. Members of the eBook team conveyed their representations widely, and team members constantly questioned what product attributes should be inferred from these representations. The metaphor "It's not a computer…it's a book!" helped engineers decide which attributes to include in the eBook and which to discard: "Someone had a long discussion about why we would need a calculator in [the eBook]. At the end, [the project manager]

Table 6 Use of Coordinating Practices by Teams with Concept Disunity

	Practice 1: Collective scrutiny of representations	Practice 2: Linking representations to design constraints	Practice 3: Active editing among representations	Evidence of concept coherence
RadCross	Consistency: LOW Data sources: M, D An engineer working on a van-based system said, "If I had heard [of the concept as a sports car and an SUV in a blender]…I would have laughed my ass off." (Design engineer)	Consistency: LOW Data sources: L, M, D "What we found was that…the company could not do it, it was too far away from our architectural capability." (Planning manager)	Consistency: LOW Data sources: L, M, D "The new concept got further and further away from the original concept [sports car and SUV in a blender]….The further they got from the concept it started testing not quite as well." (Marketing manager)	Result: LOW Data sources: L, M "You had engineering. You had planning. You had marketing. You had finance. All of them have slightly different interpretations of what it is that we're trying to achieve." (Senior planning analyst)
eBook	Consistency: HIGH Data sources: L, M, D "We had a big meeting with [the executive manager], he came in with a…mock-up, a model of what an eBook might look like." (Software engineer)	Consistency: LOW Data sources: L, M, D "It suffered from a classic chicken-and-egg problem. What good is an electronic book if you don't have any content?" (Designer)	Consistency: LOW Data sources: L, M, D Strong initially with metaphor of "It's a book!" but the team failed to update this when book content was not available. (Project leader)	Result: LOW Data sources: L, M It was recalled that eBook was presented "partially as a consumer product, and partially as an enterprise solution. And we did both, and focus is about doing one, [*laughs*] so that was a bit of a struggle." (Project leader)
BodyCool	Consistency: HIGH Data sources: L, M "The founders described some really dramatic performance enhancement capabilities…they showed a prototype….It was actually very compelling." (Design engineer)	Consistency: LOW Data sources: L, M Strong attempts to link to new markets, such as military and medical, but weak initial linking to test basic premise. (Lead engineer)	Consistency: LOW Data sources: L, M "It was pretty confusing…because [BodyCool] didn't know whether they were a medical company or a sports company." (Engineer)	Result: LOW Data sources: L, M "We still haven't quite figured out exactly whom we are selling these to…and what they need it to look like, and feel like." (Engineer, at launch)

Note. L, leader interviews; M, member interviews; D, archival data.

would go, 'But it's a book!' And it was very helpful for keeping us all focused and communicating to people." If books did not have calculators, to be consistent with that metaphor, neither should the eBook. In another instance, the question of whether to allow a list of contacts on the eBook was addressed differently. The executive manager explained that "someone can have a little black book of names [which] is a book also. So it fits the paradigm." Because concept representations conveyed only limited information, to be used effectively, team members needed to engage with representations in use, question their conceptual limits, and resolve differences in interpretation to collectively define the attributes the product would include.

When team members did not share concept representations widely and did not provide members the opportunity to question competing interpretations, team members developed disparate views of the evolving product concept, lacked full knowledge of the representations in use, or outright rejected them. The RadCross team crafted several representations, but without collective scrutiny, these representations were either remembered differently or not embraced equally by all team members. As a result, differences in interpretation were not identified and could not be resolved. The RadCross team had a full-size prototype that generated excitement and a metaphor that represented a new type of crossover vehicle—a sports car and an SUV in a blender—but they did not convey these representations broadly and allow team members to scrutinize, compare, and discuss competing interpretations. A frustrated RadCross planning analyst explained that "the biggest challenge was [how] to say this is what this [concept] wants to be, and to do that consistently in a language that worked [across the organization]. We struggled with that… ." As shown in Table 6, some project members did not even hear of this metaphor and so it did not inform their design work, with one bluntly stating that "if I had heard [of the concept as a sports car and an SUV in a blender]…I would have laughed my ass off."

Without collective scrutiny, some members of the RadCross team rejected representations crafted by other team members. Designers thought a North Face jacket's pockets and zippers conveyed rugged multifunctionality that could inform the design of the vehicle, but this was not broadly shared within the team. Upon learning of the jacket metaphor, two engineers rejected this representation, one referring to the jacket as "*their* wardrobe analogy": "If you are working with the [designer], they tell you what it is they are trying to go after; that is *their* wardrobe analogy." Although the jacket metaphor was remembered, it was viewed as insignificant and did not inform the engineers' design decisions: "To be honest…they [designers] really don't have to show us any of this stuff because we're going to be sitting there with our blinders on and working on fuel systems and nothing else anyway, so what is the difference?" Without collective scrutiny across the entire team, the jacket's meaning was not equally valued. In the end, the gas cap the engineers designed had to be reworked because it did not mesh with the vehicle's exterior design. Whereas the rest of the car communicated a masculine utility vehicle, the gas cap was small, elegant, streamlined, and visually out of synch with the car's exterior.

Collective scrutiny enabled team members to assess representations introduced, surface differences, and reconcile varying individual interpretations among the team. When teams engaged in collective scrutiny, they discovered sources of difference and produced agreement on how to interpret representations. Because novel products lack existing templates to reference, representations were a critical but abstract resource. Thus, it was imperative for teams to ensure that any references introduced were interpreted by team members in the same way. The one team that did not consistently engage in collective scrutiny, the RadCross team, did not even develop a shared repertoire: representations relevant to designers were not relevant to engineers. This fostered the beginnings of concept disunity and, in the case of the gas cap, created rework and delay. Collective scrutiny on its own did not help teams achieve concept coherence. Team members also needed to evaluate how representations held up to design constraints.

Linking Representations to Design Constraints. A design constraint could be any technical or market limitation that restricted how the concept could be translated into a viable product. For example, a pocket rocket metaphor for a new small car may not be feasible if a powerful engine will not mesh with the car's frame. Teams that consistently linked representations to design constraints did two activities: (1) they linked their representations to one or more design constraints early in the development process, and (2) they continuously checked their concept assumptions with emerging design constraints. Because product concepts were still being developed, it was too early to test final product performance. Linking representations to design constraints was a precursor to a formal test of the completed product concept. As shown in Table 5, the PDAPhone, JointCool, and FlexTruck teams consistently used this practice. As shown in Table 6, the eBook, BodyCool, and RadCross teams made either weak or inconsistent use of this practice.

Setting early design constraints provided focus by narrowing the team's options for exploration. Even if the constraint was later changed, early design constraints fostered the team's ability to select representations and make design decisions that moved the project forward to test new ideas. Constraints enabled progress by helping team members make coherent design decisions. For example, the FlexTruck team set an early design constraint: they chose a platform for their new flexible truck that constrained the representations introduced. As one project manager explained, by selecting a platform early in the process, "We could shelve the alternatives, concentrate on our [flexible cargo area], and, most important, figure out how much stuff we were not going to change." Early design constraints defined the parameters of novelty: the flexible cargo was novel, but the team was not starting from scratch, and any representations introduced would have to align with the chosen platform. The PDAPhone team set early design constraints with a "concept box" specifying key attributes the product would need. This box of constraints narrowed the options available for the product concept, suggesting the dimensions of a physical prototype that would be acceptable. As one executive manager explained, "If you are spending a lot of time talking about stuff that is not in this 'box,' then…you are talking about something that doesn't matter. It's actually a very good focusing tool…."

Teams that continually linked representations to design constraints learned how representations would operate in practice even as their product concept evolved. When the FlexTruck team confronted the challenge of how to create a convertible, waterproof cargo bed, the project leader recounted how the team "did some customer research, so they had some data to base the decision. With cameras running, we asked people to load up some nursery supplies like flowers and peat moss and a wheelbarrow, things like that…." Such experiments, which the team called "proof points," enabled them to see if the Swiss Army knife metaphor of instant convertibility was met when a customer wished to quickly adapt the truck to haul messy garden supplies. By video recording these sessions, the feedback obtained could be shared with the entire team. When done consistently, linking to design constraints produced new information available to everyone working on the next set of design iterations.

The three teams that did not link representations with design constraints experienced concept disunity as product development progressed. When the FlexTruck team produced a prototype, it represented what was feasible, which allowed the team to collect valuable user input to tailor the product created. In contrast, the "show vehicle" prototype produced by RadCross bore little relationship to a manufacturable product. A RadCross senior planning analyst lamented that "show cars often do more harm than good. Sometimes they promise a little too much because they are so beautiful.... The show car had big beefy tires and wheels. We knew that wasn't going to be a part of the production car." This disparity enhanced ambiguity as to what attributes the final product would include, opening opportunities for team members to maintain disparate interpretations of the product.

Linking representations to design constraints helped focus team members' attention on core product attributes and enabled team members to coordinate individual design tasks while the parameters of the product concept unfolded. Coordinating individual design tasks would be simple if the product concept was known at the outset. However, the teams we studied were trying to coordinate design tasks on a moving target. Teams that continuously linked concept representations to design constraints aligned individual interpretations as the product concept evolved—achieving concept coherence despite the fact that the concept itself was changing. Linking representations to design constraints was a critical way to obtain more data on the feasibility of design ideas and bound the repertoire before a formal test could take place. If representations did not link well with design constraints, they could be removed from the repertoire with active editing.

Active Editing Among Representations. With stories, metaphors, prototypes, and changing design constraints in play, teams struggled to maintain concept coherence as they iterated through different ideas. To ensure that representations were working toward the same objective, three teams actively edited their repertoire of concept representations to resolve incompatibilities, as shown in Table 5. Active editing could arise from the need to choose between conflicting representations or from new design constraints that challenged the appropriateness of an existing representation. Most often, active editing integrated what the team learned from collective scrutiny and linking to design constraints. Active editing required two activities: (1) a clearly identified process owner designated to make changes to concept representations and (2) a public editing process that allowed representations that no longer fit the product concept to be excised from the repertoire.

Active editing could resolve competing representations that were technically feasible but incompatible. For example, the PDAPhone team initially had two types of prototypes: a "flip phone" and a "stick phone." Early on, there was uncertainty as to which was desired, but when the product architect made it clear which path would be taken, this decision was clearly conveyed throughout the team: from this point forward, all representations were in the flip phone style. The lead engineer recalled, "I disagreed that we should do a flip phone. I felt like we should do a stick. And in the end, [the product architect] said, 'We're doing a flip phone.' I was like, 'Okay.'" Without a person designated to change representations in use, disparity over the PDAPhone form might have persisted and led to competing interpretations of the product's design. Later in the project, active editing helped team members adapt to a new design constraint. When the chief product architect saw another firm successfully implement a new interface that differed from the one the PDAPhone team was developing, he immediately revised the prototypes in use and communicated the change to all team members, making the change very public. A lead engineer explained that although the team had spent a lot of effort on the existing interface, "All of a sudden, 'boom'! He is totally [in the new user interface] camp"; after collectively questioning the new interface representation, the rest of the team joined that camp. Atlhough the team ultimately decided to launch the product with both options, the team was united in creating the new interface as the preferred option.

Teams that did not sufficiently engage in active editing failed to synchronize their repertoire of representations with changes that emerged from linking to design constraints, as shown in Table 6. For example, once the eBook team realized that there was not enough digital content available to make its electronic book viable, the team changed its concept for its first product to be a tablet device for delivery drivers. Yet the team continued using the metaphor "It's a book!" and continued using book-like prototypes to inform its design work—even though delivery drivers do not read books while driving. Although the story of its intended use changed from book-like to a tablet-like application, the book metaphor and prototypes persisted even though their relevance had waned. Without actively editing the repertoire of representations in use, misunderstandings among team members produced concept disunity. To not only create but also maintain a common understanding of desired product attributes, representations needed to change when the product concept changed.

When incompatible interpretations of representations persisted and were not edited out of the repertoire, teams were undecided as to how they should translate concepts into products. Rather than reduce tensions between incompatible representations, the BodyCool team moved rapidly between a sports application, a hospital application, and a military application. As a lead engineer commented, "[We] changed a couple of times back-and-forth between this medical company and a sports company...in the meantime we tried to stay focused on getting our prototypes done." As shown in Table 6, without active editing of the repertoire of representations, team members were confused as to the product's target audience, which delayed production of a prototype that could have provided the team with useful feedback.

All six teams crafted a repertoire of at least three types of representations that could be in play at any one time. Thus, the practice of active editing was critical to fostering concept coherence as the product concept evolved. It became particularly important in the project's later stages when concept representations began to proliferate. Active editing facilitated the creation of a common understanding of representations that would inform the product concept by bounding the repertoire from which team members could draw to inform their design work and by removing rejected representations from consideration.

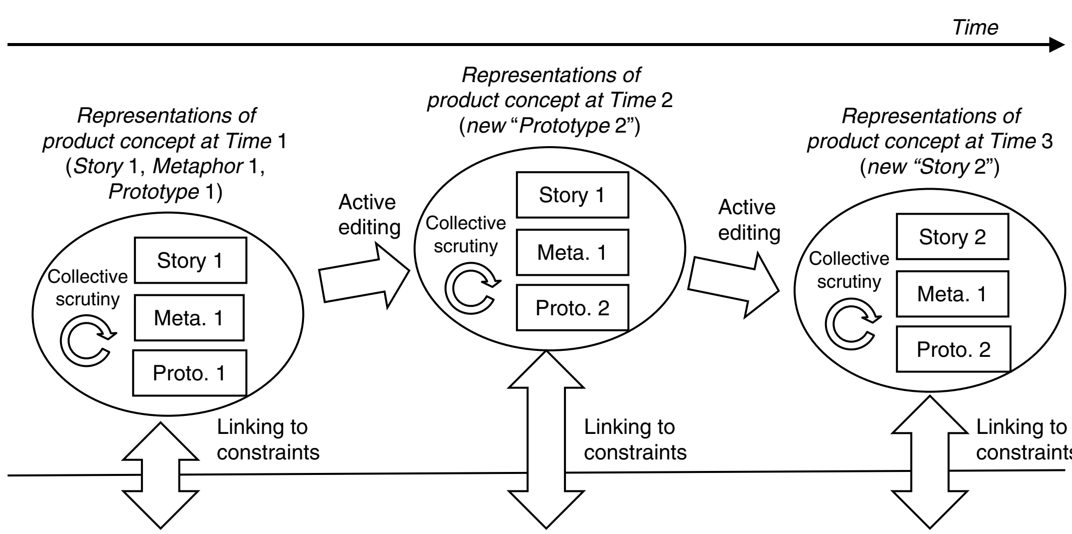
The Dynamics of Managing a Repertoire. Whereas we presented the practices that contribute to concept coherence sequentially, the process of maintaining coherence was dynamic and iterative, as illustrated in Figure 3. All three coordinating practices were used to clarify and corral representations to create common understanding; the iterative use of these practices continued as the concept evolved.

Consider the case of FlexTruck. Early in the FlexTruck project (Time 1 in Figure 3), the primary representations included a story (the story of a naïve customer assuming flexibility was possible), a metaphor (the "Swiss Army knife"), and a prototype (the "theme model" which presumed electric changeover). Taken together, the story, metaphor, and prototype representations helped define attributes of the product concept; they also defined the repertoire of representations in use (the single oval at Time 1 in Figure 3). To achieve a common understanding of how each representation was interpreted, team members engaged in collective scrutiny. For example, the Swiss Army knife metaphor could imply ease of conversion from one tool to another or the use of many different functions. By discussing the metaphor, the team agreed on a common interpretation: the ease of conversion. As work progressed, the team linked to design constraints (the thick double-tipped arrow in Figure 3) and determined it was not possible to manufacture the electric-change mechanism inherent in the theme model prototype. FlexTruck's executive leader joked that they "locked 10 guys in a conference room" to create a new design solution.

The team not only designed a manual solution to the problem but also came up with a new representation from a legendary 1968 sports car to help explain what the final product concept should do. As a member of the FlexTruck team related, "The concept was there [but] there were some prototypes that did not work at all. So, what we had to do, we had to come in and fix the concept." In this case, "fixing the concept" meant actively editing away representations that no longer fit and introducing the new 1968 sports car representation. By Time 2 in Figure 3, the team agreed on a repertoire of representations that fit a revised product concept. The specific product attributes changed (from electric to manual), but the team still maintained concept coherence. This process continued with each iteration of the product concept as new constraints emerged. In the end, the FlexTruck vehicle was considered a successful and interesting new entry to the market not only by those who worked on the project but also by automobile reviewers, one of whom considered it "a near-ideal" vehicle for the suburban family homeowner.

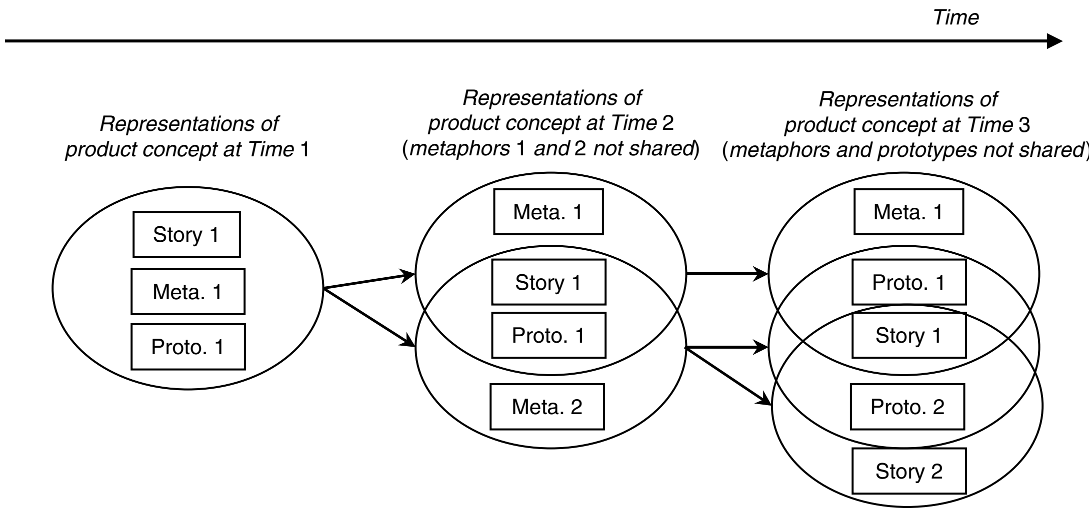
Figure 4 illustrates how concept disunity can result from inconsistent use of coordinating practices, which

Figure 3 Dynamic Illustration of Managing a Repertoire of Representations to Maintain Concept Coherence



Notes. Ovals denote the product concept as a repertoire of representations shared by team members. Arrows denote the application of coordinating practices. Movement of ovals denotes coordinated changes in representations over time. Refer to text for an example.

Figure 4 Dynamic Illustration of Failure to Manage a Repertoire of Representations Leading to Concept Disunity



Notes. Multiple ovals denote a lack of a shared repertoire of representations. Refer to text for an example.

we describe using the case of RadCross. The RadCross team had three dominant representations (Time 1 in Figure 4): a story related to the rise of the crossover segment, a metaphor of a sports car and an SUV in a blender, and a show-car prototype that featured beefy tires and high ground clearance. The RadCross team was late in linking to design constraints, leaving open which vehicle platform to use. At Time 2, there were two metaphors in play: the "sports car and SUV" and the "sports car and van" in a blender. Different team members referenced different metaphors: no common repertoire was created. By Time 3, there were many competing metaphors and prototypes. Without active editing, team members used different sets of representations (multiple ovals in Figure 4), which prevented them from drawing on a common repertoire. This led to concept disunity, where individuals pursued design tasks unaware of how they were deviating from others. One RadCross executive manager was frustrated with the number of representations in use: "There were 5 different styling execs ... 25 scale models [and] 10 full-sized clay [models]." Several team members maintained their own representations, which increased ambiguity as to which representations best represented the concept. The result was a combination of delay and rework, with some incompatibilities unaddressed even at launch. Referring to the mix of attributes embodied in the final product, one national publication described the RadCross product as "bizarre" in its final form.

Discussion

Prior research has shown how concept representations enable collectives to bridge different domains (Bechky 2003a, Carlile 2002) and help leaders direct individuals' attention to strategic initiatives (Kaplan 2008, Tripsas 2009). Yet these two bodies of research have not identified boundary conditions that explain when representations either enable or impede coordination. All of the teams we studied crafted at least three types of concept representations to represent different facets of novel product concepts, such as need, function, and form, but crafting a repertoire of representations was not sufficient to ensure a common understanding of design tasks. Representations themselves do not foster coordination but require coordinating practices to manage a repertoire of representations in use. We provide a dynamic theoretical understanding of how representations are used, challenged, and revised by all parties involved. Our research identified three practices that enabled teams to achieve two distinct modes of common understanding needed to provide concept coherence and support the coordination of design tasks. Without consistent use of these coordinating practices, a proliferation of representations contributed to competing interpretations and misunderstandings, resulting in concept disunity.

Although many scholars appreciate the importance of a repertoire in enabling collective action, few have examined how such toolkits are crafted and actively managed at the project level. In doing so, we make a distinct contribution to theories of innovation and coordination. First, our research shows that the effects of concept representations are not always positive but depend on consistent use of coordinating practices to manage the repertoire of representations in use. Second, whereas much of the existing research shows how achieving a common understanding is important for coordination, our research identifies two specific modes of common understanding that are necessary for coordination to occur. Finally, we show that product concepts do not stand still and that creating concept coherence within a team is an ongoing accomplishment in dynamic environments.

Managing the Repertoire. Our research suggests that repertoires of representations bring some benefit: rather than rely on a single representation to perfect the teams' vision, the teams in our study relied on three types of representations to convey product need, function, and form. One type of representation was inadequate to achieve this complex goal. A repertoire of representations might be more effective than one type, as individuals are cognitively more aware of information accessed through verbal and visual channels as opposed to information presented in only one form (Paivio 1986). For example, drawings and prototypes together are more effective than one domain on its own (Henderson 1995), as each type contributes different information to the task at hand. Although the benefits of "dual coding" have been robustly demonstrated (Paivio 1986), organizational theorists tend to assume that a single guiding metaphor or object can help coordinate activity (Clark and Fujimoto 1991). This is despite the fact that the many specialists that contribute to complex innovations are likely to maintain disparate thought worlds and vocabularies (Bechky 2003a, Dougherty 1992, Leonardi 2011). Given our findings, relying on a single representation may be unlikely to provide sufficient information to enable coordination of complex novel innovation efforts. If innovation is the product of recombining disparate elements (Hargadon and Sutton 1997), then it makes sense that multiple representations are needed to convey what the potential new combinations can bring to novel innovations.

However, theorists tend to assume that individuals draw from a well-defined and well-understood set of choices, where what constitutes the repertoire is unproblematic. Our research questions this assumption and problematizes how teams establish agreement on what constitutes the repertoire. Repertoires influence action by shaping the set of actions from which individuals draw to solve complex problems (Kellogg 2011, Leonardi 2011, Rindova et al. 2011, Swidler 1986). By doing so, they both permit appropriate strategies of action and bound or limit that range of action (Swidler 1986). Although all of our teams used multiple types of concept representations, not all of them succeeded in creating a shared repertoire. In these cases, different people on the same team contributing to the same innovation maintained disparate interpretations of the representations in use and disagreed about what representations constituted the repertoire. When innovation depends on the coordination of interdependent work, the creation of a common repertoire of representations can advance a team's common understanding of their innovation goal, whereas the lack thereof can fracture it. When unmanaged, multiple representations allowed competing interpretations to persist, which fostered concept disunity.

The ultimate effect of a repertoire of representations of the coordination of innovation is conditional: only when used in conjunction with three coordinating practices did repertoires foster a common understanding of desired attributes. Although the idea of revising product design as new market or technical information is discovered is not novel (MacCormack et al. 2001), our contribution is to highlight that if product attributes change, so too must their representations for teams to maintain a common understanding of the product concept while it is being developed. Thus, repertoires work by not only providing information in multiple ways but also by defining the range of strategies for action (Swidler 1986), and this limiting function helps loosely orchestrate the work of many to create a product with the integrity of being designed by one mind. This structuring action defines the menu of choices from which organizational members draw—providing freedom for action within those bounds (e.g., Orlikowski and Yates 1994). When agreement on what falls within the set fails, so too does the coordinating power of the repertoire. Thus, in addition to guiding people and tasks, project leaders must also consider managing the repertoire of representations from which teams draw to create novel innovations. Thus tools of symbolic management can be used not just to shape culture but also to shape the actual repertoire of work products teams use. By fostering engagement, questioning representations, and editing the repertoire as it evolves, project leaders can benefit from the rich information repertoires provide without succumbing to their risks.

The Dynamics of Coordinating in Practice. Theories of coordination have embraced routines, boundary objects, practices, and frames as important in facilitating coordination. In their comprehensive review, Okhuysen and Beckhy (2009) suggested that these mechanisms foster the common understanding needed to coordinate interdependent work. With few exceptions (e.g., Nicolini et al. 2012), it is often assumed that representations will have a positive effect on coordination. Our research questions this tenant and shows that multiple competing representations can create misunderstandings as easily as common understandings. To achieve concept coherence and support coordination, teams needed to reference a common repertoire of representations and interpret them the same way. Our contribution is to specify how these two different modes of common understanding are produced.

Without collective scrutiny of representations, team members remembered them differently or rejected them out of hand. Collective scrutiny of representations enabled team members to understand novel concepts in new ways by inviting questions and reconciling disagreements. Members of the eBook team not only were aware of the metaphor "It's a book!" but also questioned the degree to which the metaphor could be applied. Promoting open questioning reduced the equivocality inherent in novel innovations, which can be subject to misunderstanding if not debated (Weick 1990). To be effective, a collective sensemaking process needs to allow for questioning (e.g., Faraj and Xiao 2006) and reconcile competing interpretations in order to convert interpretation into facilities for action (Weick et al. 2005).

Linking representations to design constraints early and continuously throughout the project was critical to enabling teams to collectively learn what aspects of their product concept were feasible. These "proof points" allowed teams to collect critical feedback on their product concepts preliminary to actual product testing. Holding the concept against the light of design constraints enabled teams to collectively generate new information to further each person's specialized task for the next iteration of design. When teams did not engage in linking to constraints, they failed to either collect or act on critical feedback. The importance of testing in product design is not novel (Brown and Eisenhardt 1997, MacCormack et al. 2001). What fostered our teams' collective learning was their linking of conceptual worlds to physical worlds prior to creating a testable product.

Collective scrutiny and linking to design constraints helped align individual interpretations, but active editing was the one practice that excised representations that were no longer relevant, thus defining the limits of what constituted the repertoire. Teams that actively edited among representations were better able to achieve both modes of common understanding as representation use evolved. When outdated representations remained in place after new information materialized, concept disunity occurred and coordination broke down. At the time of product launch, BodyCool team members still did not know whether they were designing a product for a sports, hospital, or military audience. It may be desirable for representations to endure (Heath et al. 2001), but this quality can also make their revision difficult and inhibit teams from adapting to new information, which is essential in fast-paced markets (Brown and Eisenhardt 1997). Thus, of the three practices, it may be even more important for teams to engage in active editing to ensure that representations in use are still relevant to the concepts being designed. The teams in our study that exhibited concept coherence kept their efforts aligned even as the product concept evolved in response to incompatibilities, design constraints, and market changes—which allowed team members to continually adapt to a dynamic product environment.

When there is ambiguity over what to create, multiple means of conveying concepts, and new information emerging, crafting concept representations facilitates coordination only when combined with coordinating practices that allow for collective questioning and revision of those representations. This suggests a very dynamic understanding of how coordination takes place, where the objects individuals are designing are themselves a moving target. Concept coherence may be effective because it helps advance all parties' understanding of design tasks as they unfold. If the process of developing novel innovations is dynamic and changes in direction inevitable (Van de Ven et al. 2008), appropriate concept representations are unlikely to be the same from start to finish. When the product direction inevitably changed, teams with concept coherence moved together; this was not because they experienced less change. All six teams confronted dramatic revisions to their product concepts, and even teams that experienced large shifts were able to achieve concept coherence. On teams that experienced concept disunity, team members had difficulty incorporating new information and adapting individual work to changes in product direction. Thus, teams that achieve concept coherence may be better able to adapt to changing market and technical conditions.

Prior research has considered coherence to be a property of the product itself (Alexander 1964, Fujimoto et al. 1996). Our research explores how concept coherence *within the team* affects the coordination of innovation. Concept coherence, like collective mind (Weick and Roberts 1993), is a construct that "does not reside in the individuals taken separately, though each individual contributes to it; nor does it reside outside them; it is present in the interrelations between the activities of individuals" (Asch 1952, p. 252, cited in Weick and Roberts 1993, p. 363). This distinction has implications for how we theorize about the connection between knowledge structures (Ocasio 1997, Walsh 1995) and the coordination of innovation. The conceptual work needed to reach concept coherence could be akin to the sensemaking that happens when new technologies are introduced (Bijker 1997). For example, collective technological frames at the industry level shape how people categorize and evaluate novel technologies (Benner and Tripsas 2012, Kaplan and Tripsas 2008). Future research could test whether products developed with concept coherence are more likely to influence other firms' behavior.

We studied product development teams, but our research has relevance to contexts characterized by interdependence, ambiguity, and the need for coordination. We found that concept coherence enabled teams to coordinate interdependent design tasks, but our study did not compare the importance of concept coherence with other factors such as team resources. Future research could examine the relative importance of such trade-offs. Our research shows that repertoires of representations can provide an efficient means for collectives developing novel products to coordinate their actions, but without coordinating practices to manage the repertoire, their ultimate effect could undermine coordination. Concept coherence is achieved not only from the gestalt produced by a repertoire of concept representations but also from the practices that guide which representations are in use and how these representations are interpreted. Examining repertoires of representations and the practices that enliven them illuminates the conceptual foundations of innovation and the role of concept coherence in dynamic environments.

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References
Alexander C (1964) *Notes on the Synthesis of Form* (Harvard University Press, Cambridge, MA).

Asch SE (1952) *Social Psychology* (Prentice-Hall, Englewood Cliffs, NJ).

Bacon G, Beckman S, Mowery D, Wilson E (1994) Managing product definition in high-technology industries: A pilot study. *Calif. Management Rev.* 36(3):32–56.

Bartel CA, Garud R (2009) The role of narratives in sustaining organizational innovation. *Organ. Sci.* 20(1):107–117.

Bechky BA (2003a) Object lessons: Workplace artifacts as representations of occupational jurisdiction. *Amer. J. Sociol.* 109(3): 720–752.

Bechky BA (2003b) Sharing meaning across occupational communities: The transformation of understanding on a production floor. *Organ. Sci.* 14(3):312–330.

Bechky BA (2006) Gaffers, gofers, and grips: Role-based coordination in temporary organizations. *Organ. Sci.* 17(1):3–21.

Benner MJ, Tripsas M (2012) The influence of prior industry affiliation on framing in nascent industries: The evolution of digital cameras. *Strategic Management J.* 33(3):277–302.

Bijker WE (1997) *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (MIT Press, Cambridge, MA).

Boje DM (1991) The storytelling organization: A study of story performance in an office-supply firm. *Admin. Sci. Quart.* 36(1): 106–126.

Boland RJ Jr, Lyytinen K, Yoo Y (2007) Wakes of innovation in project networks: The case of digital 3-D representations in architecture, engineering, and construction. *Organ. Sci.* 18(4): 631–647.

Brooks FP (1995) *The Mythical Man-Month: Essays on Software Engineering*, anniversary ed. (Addison-Wesley, Reading, MA).

Brown SL, Eisenhardt KM (1995) Product development: Past research, present findings, and future directions. *Acad. Management Rev.* 20(2):343–378.

Brown SL, Eisenhardt KM (1997) The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations. *Admin. Sci. Quart.* 42(1):1–34.

Carlile PR (2002) A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organ. Sci.* 13(4):442–455.

Carlile PR (2004) Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organ. Sci.* 15(5):555–568.

Clark KB (1985) The interaction of design hierarchies and market concepts in technological evolution. *Res. Policy* 14(5):235–251.

Clark KB, Fujimoto T (1991) *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry* (Harvard Business School Press, Boston).

Clark P, Staunton N (1989) *Innovation in Technology and Organization* (Routledge, London).

Clemens ES (1993) Organizational repertoires and institutional change: Women's groups and the transformation of U.S. politics, 1890–1920. *Amer. J. Sociol.* 98(4):755–798.

Dahl DW, Moreau P (2002) The influence and value of analogical thinking during new product ideation. *J. Marketing Res.* 39(1):47–60.

Dougherty D (1992) Interpretive barriers to successful product innovation in large firms. *Organ. Sci.* 3(2):179–202.

Dougherty D (2001) Reimagining the differentiation and integration of work for sustained product innovation. *Organ. Sci.* 12(5): 612–631.

Eisenhardt KM (1989) Building theories from case study research. *Acad. Management Rev.* 14(4):532–550.

Etzion D, Ferraro F (2010) The role of analogy in the institutionalization of sustainability reporting. *Organ. Sci.* 21(5):1092–1107.

Ewenstein B, Whyte J (2009) Knowledge practices in design: The role of visual representations as "epistemic objects." *Organ. Stud.* 30(1):7–30.

Faraj S, Xiao Y (2006) Coordination in fast-response organizations. *Management Sci.* 52(8):1155–1169.

Feldman MS, Pentland BT (2003) Reconceptualizing organizational routines as a source of flexibility and change. *Admin. Sci. Quart.* 48(1):94–118.

Fiol CM (1989) A semiotic analysis of corporate language: Organizational boundaries and joint venturing. *Admin. Sci. Quart.* 34(2):277–303.

Fujimoto T, Iansiti M, Clark KB (1996) External integration in product development. Nishiguchi T, ed. *Managing Product Development* (Oxford University Press, New York), 121–161.

Goffman E (1974) *Frame Analysis: An Essay on the Organization of Experience* (Harper & Row, London).

Hargadon A, Douglas Y (2001) When innovations meet institutions: Edison and the design of the electric light. *Admin. Sci. Quart.* 46(3):476–501.

Hargadon A, Sutton RI (1997) Technology brokering and innovation in a product development firm. *Admin. Sci. Quart.* 42(4): 716–749.

Heath C, Heath D (2007) *Made to Stick: Why Some Ideas Survive and Others Die* (Random House, New York).

Heath C, Bell C, Steinberg E (2001) Emotional selection in memes: The case of urban legends. *J. Personality Soc. Psych.* 81(6):1028–1041.

Henderson K (1995) The political career of a prototype: Visual representation in design engineering. *Soc. Problems* 42(2):274–299.

Jarzabkowski PA, Lê JK, Feldman MS (2012) Toward a theory of coordinating: Creating coordinating mechanisms in practice. *Organ. Sci.* 23(4):907–927.

Kaplan S (2008) Framing contests: Strategy making under uncertainty. *Organ. Sci.* 19(5):729–752.

Kaplan S, Tripsas M (2008) Thinking about technology: Applying a cognitive lens to technical change. *Res. Policy* 37(5):790–805.

Katz R, Allen TJ (1985) Project performance and the locus of influence in the R&D matrix. *Acad. Management J.* 28(1):67–87.

Kelley T (2001) *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm* (Doubleday, New York).

Kellogg KC (2011) Hot lights and cold steel: Cultural and political toolkits for practice change in surgery. *Organ. Sci.* 22(2): 482–502.

Kellogg KC, Orlikowski WJ, Yates J (2006) Life in the trading zone: Structuring coordination across boundaries in postbureaucratic organizations. *Organ. Sci.* 17(1):22–44.

Lawrence PR, Lorsch JW (1967) *Organization and Environment: Managing Differentiation and Integration* (Graduate School of Business Administration, Harvard University, Boston).

Leonardi PM (2011) Innovation blindness: Culture, frames, and cross-boundary problem construction in the development of new technology concepts. *Organ. Sci.* 22(2):347–369.

Lounsbury M, Glynn MA (2001) Cultural entrepreneurship: Stories, legitimacy, and the acquisition of resources. *Strategic Management J.* 22(6–7):545–564.

Lynn GS, Morone JG, Paulson AS (1996) Marketing and discontinuous innovation: The probe and learn process. *Calif. Management Rev.* 38(3):8–37.

MacCormack A, Verganti R, Iansiti M (2001) Developing products on "Internet time": The anatomy of a flexible development process. *Management Sci.* 47(1):133–150.

Martens ML, Jennings JE, Jennings PD (2007) Do the stories they tell get them the money they need: The role of entrepreneurial narratives in resource acquisition. *Acad. Management J.* 50(5): 1107–1132.

Martin J (1982) Stories and scripts in organizational settings. Hastorf A, Isen A, eds. *Cognitive Social Psychology* (Elsevier, New York), 255–305.

Nicolini D, Mengis J, Swan J (2012) Understanding the role of objects in cross-disciplinary collaboration. *Organ. Sci.* 23(3):612–629.

O'Connor GC, Rice MP (2013) New market creation for breakthrough innovations: Enabling and constraining mechanisms. *J. Product Innovation Management* 30(2):209–227.

Ocasio W (1997) Towards an attention based view of the firm. *Strategic Management J.* 18(S1):187–206.

Okhuysen GA, Bechky BA (2009) Coordination in organizations: An integrative perspective. *Acad. Management Ann.* 3(1):463–502.

Orlikowski WJ, Yates J (1994) Genre repertoire: The structuring of communicative practices in organizations. *Admin. Sci. Quart.* 39(4):541–574.

Orr JE (1996) *Talking About Machines: An Ethnography of a Modern Job* (ILR Press, Ithaca, New York).

Ortony A (1975) Why metaphors are necessary and not just nice. *Ed. Theory* 25(1):45–53.

Ortony A (1993) Metaphor, language, and thought. Ortony A, ed. *Metaphor and Thought*, 2nd ed. (Cambridge University Press, Cambridge, UK), 1–16.

Paivio A (1986) *Mental Representations: A Dual Coding Approach* (Oxford University Press, New York).

Petrie HG, Oshlag RS (1993) Metaphor and learning. Ortony A, ed. *Metaphor and Thought*, 2nd ed. (Cambridge University Press, Cambridge, UK), 579–609.

Rindova V, Dalpiaz E, Ravasi D (2011) A cultural quest: A study of organizational use of new cultural resources in strategy formation. *Organ. Sci.* 22(2):413–431.

Rosa JA, Porac JF, Runser-Spanjol J, Saxon MS (1999) Sociocognitive dynamics in a product market. *J. Marketing* 63(Special issue):64–77.

Schön DA (1993) Generative metaphor: A perspective on problem-solving in social policy. Ortony A, ed. *Metaphor and Thought*, 2nd ed. (Cambridge University Press, Cambridge, UK), 137–163.

Schrage M (1999) *Serious Play: How the World's Best Companies Simulate to Innovate* (Harvard Business School Press, Boston).

Seidel VP (2007) Concept shifting and the radical product development process. *J. Product Innovation Management* 24(6): 522–533.

Shane SA, Ulrich KT (2004) Technological innovation, product development, and entrepreneurship in management science. *Management Sci.* 50(2):133–144.

Sillince J, Jarzabkowski P, Shaw D (2012) Shaping strategic action through the rhetorical construction and exploitation of ambiguity. *Organ. Sci.* 23(3):630–650.

Simon HA (1996) *The Sciences of the Artificial*, 3rd ed. (MIT Press, Cambridge, MA).

Snow DA, Rochford EB Jr, Worden SK, Benford RD (1986) Frame alignment processes, micromobilization, and movement participation. *Amer. Sociol. Rev.* 51(4):464–481.

Star SL, Griesemer JR (1989) Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. *Soc. Stud. Sci.* 19(3):387–420.

Stigliani I, Ravasi D (2012) Organizing thoughts and connecting brains: Material practices and the transition from individual to group-level prospective sensemaking. *Acad. Management J.* 55(5):1232–1259.

Swidler A (1986) Culture in action: Symbols and strategies. *Amer. Sociol. Rev.* 51(2):273–286.

Tilly C (1993) Contentious repertoires in Great Britain, 1758–1834. *Soc. Sci. Hist.* 17(2):253–280.

Tripsas M (2009) Technology, identity, and inertia through the lens of "The Digital Photography Company." *Organ. Sci.* 20(2): 441–460.

Tripsas M, Gavetti G (2000) Capabilities, cognition, and inertia: Evidence from digital imaging. *Strategic Management J.* 21(10–11): 1147–1161.

Van de Ven AH, Polley DE, Garud R, Venkataraman S (2008) *The Innovation Journey* (Oxford University Press, New York).

Walsh JP (1995) Managerial and organizational cognition: Notes from a trip down memory lane. *Organ. Sci.* 6(3):280–321.

Weick KE (1990) Technology as equivoque: Sensemaking in new technologies. Goodman PS, Sproull L, eds. *Technology and Organizations* (Jossey-Bass, San Francisco), 1–44.

Weick KE, Roberts KH (1993) Collective minds in organizations: Heedful interrelating on flight decks. *Admin. Sci. Quart.* 38(3):357–381.

Weick KE, Sutcliffe KM, Obstfeld D (2005) Organizing and the process of sensemaking. *Organ. Sci.* 16(4):409–421.

Yin RK (1994) *Case Study Research: Design and Methods*, 2nd ed. (Sage, Thousand Oaks, CA).

Zeiss R, Groenewegen P (2009) Engaging boundary objects in OMS and STS? Exploring the subtleties of layered engagement. *Organization* 16(1):81–100.

Zott C, Huy QN (2007) How entrepreneurs use symbolic management to acquire resources. *Admin. Sci. Quart.* 52(1):70–105.

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