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Wellsprings of Creation: How Perturbation Sustains Exploration in Mature Organizations

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Abstract Organizations struggle to balance simultaneous imperatives to exploit and explore, yet theorists differ as to whether exploitation undermines or enhances exploration. The debate reflects a gap: the missing mechanism by which organizations break free of old routines and discover new ones. We propose that the missing link is *perturbation*: novel stimuli that disrupt the execution of specialized routines. Perturbation creates opportunities for organizations to invoke exploratory, general-purpose problem-solving routines. In mature organizations, perturbations become increasingly scarce to the point that exploration is stifled and inertia sets in. We suggest that mature organizations can sustain exploration by deliberately inducing perturbations in their own processes. Our theory yields testable hypotheses about the relationships between exploitation, perturbation, and exploration. We provide illustrations from The Toyota Motor Company to show how deliberate perturbation enables efficient exploration in the midst of intense exploitation.

1. Introduction

"Stability is not through counteracting the perturbing forces, but by utilizing them as a wellspring of creation"
H. von Foerster (1984: 22)

Organizations struggle to balance simultaneous imperatives to exploit and explore, yet theorists debate whether exploitation undermines or enhances exploration (e.g., Gupta, Smith and Shalley 2006). On one side of the debate, some researchers model the relationship as a unidirectional path leading from innovation to inertia by way of process control (Abernathy 1978; Benner and Tushman 2002; 2003). In direct opposition to this view, other researchers assert that exploitation provides the foundation and tools that enable exploration (Nelson and Winter 1982; Adler, Goldoftas and Levine 1999; Zollo and Winter 2002). This debate implies the existence of an as yet undefined contingency, a mechanism that determines whether organizations remain trapped within the confines of old routines or break free and discover new ones. We propose that the missing mechanism is perturbation: novel stimuli that disrupt the execution of specialized routines. When perturbations are present, organizations sustain productive cycles of exploration and exploitation. Without perturbations, exploitation drives out exploration (see Figure 1). If perturbation can be brought to the service of organizational goals, then the conflict between exploration and exploitation may prove not an inevitable dialectic of organization, but rather a byproduct of inferior leadership and administrative capabilities (Helfat et al. 2007; Adler et al. 2009; Agarwal and Helfat 2009).

****************************Insert Figure 1 about here****************************

Perturbations create opportunities for organizations to shift from specialized exploitive routines to general-problem-solving exploratory routines. To conserve resources, organizations develop specialized routines that embed domain-specific knowledge (Nelson and Winter 1982; March and Simon 1993). By exploiting domain-specific knowledge, specialized routines achieve efficient and predictable outcomes within the particular problem domains for which they were developed. When organizations possess no suitable specialized routines to exploit, they use general-purpose problem-solving routines to explore (Simon 1977: 47). General-purpose routines are more flexible than specialized routines, but also dramatically less efficient and inherently unpredictable. In organizations that possess specialized routines to handle familiar stimuli, stable execution of those routines continues until the organization either shifts it strategy or detects performance losses. Such perturbations trigger a shift from specialized to general problem solving routines (c.f. Nelson and Winter 1982: 129-130; March and Simon 1993: 161). Thus perturbations are necessary to sustain exploration in mature organizations.

Perturbations are not entirely exogenous to organizations. Rather, agency influences the quantity and quality of perturbations experienced by an organization, as well as the extent and efficiency of the exploration triggered by perturbations. Agency operates through two distinct mechanisms: deliberate perturbation and exploratory interpretation (see Figure 2). Deliberate perturbation induces perturbations in processes that would otherwise remain stable. Exploratory interpretation invokes general-purpose problem-solving routines in response to perturbations. As prior research explains the independent role of exploratory interpretation (Schön 1983; Lant, Milliken and Batra 1992; Nonaka 1994; Gilbert 2006), we focus here on deliberate perturbation and how the two mechanisms interact. While perturbations introduce potentially destructive variance into organizational processes, empirical evidence indicates that deliberate perturbation can coexist with or even enhance an organization's capacity for exploitation. We employ the Toyota Motor Company as an illustration of how these mechanisms enable, over decades, efficient exploration in the midst of intense exploitation.

This paper makes several contributions to the literature. First, we show how introducing perturbation as a mediating mechanism helps reconcile the debate on the relationship between exploitation and exploration. Our definition of perturbation as a mechanism that occasions switching from exploitive, specialized routines to exploratory, general-purpose routines extends the routine-based theory of organizational action and knowledge. Third, by explaining how agency influences the way organizations experience and respond to perturbations, we advance recent efforts to integrate agency into the theory of routine-based organizational action and dynamic capabilities (Feldman 2000; Feldman and Pentland 2003; Helfat and Peteraf 2003; Helfat et al. 2007).

2. Theories of exploration and exploitation

The concepts of exploration and exploitation trace their roots to March and Simon's (1993) division of organizational activity into problem-solving activity and performance programs. Problem-solving activity is characterized by searches in unknown territories that yield unpredictable results. By contrast, performance programs are streamlined procedures that exhibit consistent and repetitive behavior. Subsequent scholarship has tended to use the term "routine" instead of "performance program" (Nelson and Winter 1982). All organizational behavior is governed by routines, but routines range from the general to the highly specialized (Simon 1977: 47). The most general problem-solving routines have no domain-specific knowledge. As such, they rely on wasteful trial-and-error techniques to discover solutions. Specialized routines encode knowledge that enables them to solve certain classes of problems efficiently and predictably (Nelson and Winter 1982: 99-100; Lenat and Feigenbaum 1987). Organizations face "choices between investments in learning and in consumption of the fruits of current capabilities" (March 1991: 84). When organizations invoke general problem-solving routines, they explore new spaces; conversely, when organizations execute specialized routines, they exploit their accumulated knowledge.

2.1 The ambidexterity imperative

Both exploitation and exploration are essential to organizational survival. Exploitation leverages costly information processing resources, enabling boundedly rational organizations to achieve dramatically higher performance than they could otherwise (Feigenbaum, Buchanan and Lederberg 1971; Lenat and Feigenbaum 1987; March and Simon 1993). Consistent execution of specialized routines also reduces waste, redundancy, and destructive uncertainty. In demanding environments, organizations aggressively exploit existing knowledge and capabilities to remain viable (Levinthal and March 1993; Jansen et al. 2006). Yet organizations cannot live on exploitation alone: taken to an extreme, stable organizational activity devoid of exploration leads to inertia and collapse (Tushman and Romanelli 1985; Levitt and March 1988). The critical importance of both exploration and exploitation implies that long-term organizational survival depends on ambidexterity—the capability to sustain both exploitation and exploration simultaneously (March 1991; O'Reilly and Tushman 2008).

The domain of organizational action within which organizations seek ambidexterity is characterized by hierarchy or nesting (March 1991; Levinthal and March 1993). High-level routines are constructed from lower-level routines by connecting lower-level routines together (March & Simon 1993: 171). This multi-level structure raises the seemingly paradoxical possibility that organizational action may be, simultaneously, both exploitation and exploration. Exploration occurs at a high level by reordering or reconfiguring the lower-level subroutines that make up the high-level routine. In this way, the high-level routine explores a variety of possible configurations while its lower-level subroutines continue to exploit their specialized knowledge by executing exactly as they have in the past. Conversely, the high-level architecture of a routine may remain stable—that is, the ordering and configuration of its subroutines do not change—while exploration occurs within the modular boundaries of the subroutines. According to Levinthal and March (1993), high and low-level exploration substitute for each other. "Refining an existing technology substitutes for recognizing a better one, and vice-versa. Strengthening abilities within an existing paradigm substitutes for finding a new one that is better, and vice versa" (Levinthal & March 1993: 101). Eventually, however, low-level exploration will exhaust the potential for performance improvement within its higher level frame, so organizational survival ultimately requires high-level exploration as well.

2.2 Conflict or complement?

Although the importance of ambidexterity is widely recognized, the nature of the relationship between exploitation and exploration is the subject of a lively intellectual debate (Adler et al. 2009; Raisch et al. 2009). Some scholars marshal compelling empirical evidence showing that exploitation gradually drives out exploration (e.g., Abernathy 1978; Levinthal and March 1993; Benner and Tushman 2002; 2003). On the other hand, another group of scholars presents similarly compelling arguments that exploitation provides a foundation for, and even facilitates, exploration (e.g., Nelson and Winter 1982; Adler et al. 1999; Zollo and Winter 2002; Feldman and Pentland 2003). We label these two perspectives the Conflict and the

Complement Schools.

According to the Conflict School, exploitation drives out exploration because exploitation depends on consistent execution of specialized routines, while exploration requires interrupting these specialized routines and invoking general-purpose routines to generate novel solutions. From this perspective, dangers lurk in management techniques such as Scientific Management and Total Quality Management that focus on eliminating process variance and adhering to defined procedures (Taylor 1911; Hackman and Wageman 1995). Although such techniques increase an organization’s capacity to exploit existing knowledge, they hamper exploratory activities such as improvisation (Miner, Bassoff and Moorman 2001) and brainstorming (Sutton and Hargadon 1996).

The Conflict School also argues that a preoccupation with low-level exploration entrenches exploitation at high levels (March 1991). The generally short payback time of low-level exploration renders it more attractive than high-level exploration, and process improvement techniques intensify this bias by heightening the salience of performance metrics that favor innovation within the framework of established high-level routines (Levinthal and March 1993). Similarly, sustained process improvement weds organizations to established technical trajectories (Dosi 1982). Process improvement often leads to tighter coupling between low-level routines, which increases the cost and risk of high-level exploration—sometimes to the point of choking it off entirely (Levinthal 1997; Rivkin 2000). Benner and Tushman (2003) conclude that process improvement “severely stunts a firm’s dynamic capabilities” in all but the most stable environments (p. 253).

The Conflict School offers a range of suggestions about how to reconcile exploration and exploitation. Some reject the possibility of reconciliation altogether, asserting that organizations are capable only of exploitation and that change takes place through variation and selection at the population level (Hannan and Freeman 1989). Christensen (1997) grants the possibility of high-level exploration, but argues that exploratory businesses must be spun out and established as independent organizational units to protect them from the inertial forces at work within the parent company. O’Reilly and Tushman (2008) and others propose structural ambidexterity, where organizations separate exploration and exploitation into differentiated sub-units integrated at the senior management level. These solutions are not entirely satisfactory, since ideally organizations would be able to "engage in exploration without foregoing the benefits of exploitation." (Levinthal 1997: 949) New activities may rely on existing knowledge and operational resources, rendering separation difficult or impossible in some cases (Taylor and Helfat 2009).

In direct contradiction to the Conflict School, the Complement School asserts that exploitation provides the foundation for exploration (Nelson and Winter 1982; Zollo and Winter 2002; Feldman and Pentland 2003). Nelson and Winter (1982) posit that "Reliable routines of well-understood scope provide the best components for new combinations" (p. 131). This view is supported by research showing that variance reduction can facilitate exploration by providing a stable environment for observation and experimentation (Bohn 1995; Zollo and Winter 2002: 341). The predictability of specialized routines enables more efficient learning by helping problem solvers to understand causal relationships more easily and explore search spaces more efficiently (Clark 1988; Bohn and Jaikumar 1992). The Complement School envisions organizations that shift back and forth quickly and continuously between exploration and exploitation (Fuller and Stopford 1994; Brown and Eisenhardt 1997; Adler et al. 1999; Nickerson and Zenger 2002; Siggelkow and Levinthal 2003; Gibson and Birkinshaw 2004).

This view is supplemented by recent research on routines showing that organizational actors engaged in executing specialized routines do not necessarily function as mindless automatons, but rather attend to their circumstances and make conscious decisions about when to modify or break away from the established routines (Greve 1998; Feldman 2000; Feldman and Pentland 2003; Howard-Grenville 2005). Some scholars argue that this process is driven by the presence of paradoxes (Osono, Shimizu and Takeuchi 2008; Lewis 2009).

The theory of dynamic capabilities explains how exploratory meta-routines modify lower-level operating routines and prevent them from ossifying (Teece, Pisano and Shuen 1997; Winter 2003). Dynamic capabilities enable firms to build alliances (Kale and Singh 2007) or acquire and integrate other firms (Helfat et al. 2007). While dynamic capabilities are an important exploratory device, the theory is silent on the underlying mechanisms that sustain dynamic capabilities. Our theory extends the recent scholarship on micro-foundations of dynamic capabilities (e.g., Zollo and Winter 2002; Teece 2007) by proposing perturbation as the mechanism that initiates exploration. This mechanism helps to reconcile the Complement School and Conflict School perspectives: perturbations enable exploration to continue amidst exploitation as envisioned by the Complement School, but when perturbations become too sparse, organizations face the inertia and stagnation predicted by the Conflict School.

3. Theoretical model

We model organizations as hierarchical bundles of interdependent processes (Nelson and Winter 1982: 124-125; March and Simon 1993: 211). These processes comprise a mixture of idiosyncratic action sequences and stable, repeated routines. At the highest level, an organization consists of a single large and enormously complex process. For the most part, this single process admits relatively neat conceptual decomposition into subprocesses: product development, manufacturing, accounting, marketing (e.g., Baldwin and Clark 2000). These subprocesses admit further decomposition into design tasks, assembly tasks, budget preparation, order placement, and so on until one reaches the actions of individual humans, computers, and machines. In this process-oriented model, exploitation refers to the construction and use of specialized routines that leverage domain-specific knowledge to solve problems efficiently. Relative degrees of exploitation can be distinguished: given two routines specialized to the same domain, one may exploit more or better knowledge than the other, yielding higher efficiency or better outcomes. Exploration refers to the use of general-problem-solving routines to generate new knowledge. Relative degrees of exploration can also be distinguished: a general-problem-solving routine that spans a larger search space (in terms of size or dimensionality) is more exploratory.[1]

In organizational action, exploration and exploitation are almost never encountered in pure forms. Processes that appear to be explorative or exploitative are actually complex, hierarchical blends of new and old (Schumpeter 1943; Cohen and Levinthal 1990; Fleming 2001). Most high-level exploration builds on existing organizational knowledge by recombining mature, lower-level routines (Nelson and Winter 1982: 100; March and Simon 1993: 171). Conversely, exploration at lower levels increases efficiency without

[1]On generality, specialization, and performance, consult Feigenbaum et al. (1971) and Lenat & Feigenbaum (1987).

changing the high-level process structure. For example, an assembly line worker may be tasked with attaching a wheel to an automobile. At the level of the assembly process, the wheel installation routine appears stable, predictable, and utterly devoid of exploration: day in and day out, the worker attaches four wheels to each auto in predetermined locations using predetermined parts and tools. At the level of the wheel attachment process, however, vigorous exploration may be occurring. The worker may be trying out alternative orders of bolt insertion, different torque gun settings, or using a cart to hold the bolts (Spear and Bowen 1999). This hierarchical interleaving of exploitation and exploration indicates that they are not inherently incompatible: they can exist simultaneously in the same process at different levels.

When exploration yields new processes, nothing guarantees that the organization will commit the new processes to memory and exploit them. The organization may promptly forget new processes, or it may commit them to memory but never bother to recall them, or it may recall them inconsistently and haphazardly (Cohen and Bacdayan 1994). Moving from exploration to exploitation requires the will and the ability to execute a process consistently over time, adhering to the template stored in memory even when the costs of minor deviations ("cutting corners") seem vanishingly small. Following Nelson and Winter (1982: 112-113) we term such will and ability control.

The benefits of exploitation are so great that organizations cannot survive without a high-level of control except in the most munificent and least competitive of environments (Finkelstein and Hambrick 1996). Indeed, without a good deal of exploitation, bounded rationality sharply limits the range of organizational achievement (Simon 1947). Organizations do not have enough cognitive capacity to reinvent every wheel, every day (March and Simon 1993). Mature organizations are characterized by robust process memory and strict adherence to stored process templates. The behavior of mature organizations consists mostly of processes that have been subjected to considerable refinement and are relatively stable.

The problem faced by mature organizations is not the failure to exploit, but the gradual erosion of their capacity to explore. As processes mature, processes function more and more smoothly. Serious reverse salients are addressed (Hughes 1983), buffers are constructed to prevent external stimuli from disrupting internal processes (Thompson 1967; Hannan and Freeman 1989), and performance expectations are brought in line with the status quo (Levitt and March 1988; March and Simon 1993; Greve 1998). When processes function smoothly and meet expectations, and external stimuli are kept at arm's length, nothing remains to prompt exploration. As a result, organizations become ossified, inflexible, and vulnerable to major environmental shifts (Abernathy 1978; Tushman and Romanelli 1985). "Sacrifice of flexibility … is the price paid for highly effective capabilities of limited scope" (Nelson and Winter 1982: 126).

Resolving the conflict between exploitation and exploration could improve organizational performance by delivering the efficiencies of intense exploitation without sacrificing adaptability. At least in theory, the hierarchical structure of exploration and exploitation should make such harmony possible: steady exploitation at one level could be combined with vibrant exploration at another level. To sustain this balance, however, some mechanism must counter the forces that bring processes under tighter and tighter control. There must be a mechanism by which organizations transition from exploitation back to exploration.

We propose that perturbation is the mechanism that bridges from exploitation to exploration. Our theoretical model, shown in Figure 2, focuses on the pathway from exploitation to exploration (the dynamics of control are explored elsewhere, e.g., Tushman and Romanelli 1985; Hannan and Freeman 1989). When organizations execute specialized routines, they behave predictably and repetitively (Nelson and Winter 1982; March and Simon 1993), giving rise to a stable equilibrium trajectory. Perturbations are stimuli that disrupt this equilibrium, knocking the system into an unexpected state that its specialized routines are not designed to handle (c.f. Mukherjee and Jaikumar 1992; Nonaka 1994). The more specialized and controlled the routine, the more precisely it dictates the equilibrium trajectory of organizational action. A perturbation occurs when the organization's state diverges from this equilibrium trajectory by any amount or for any duration. Perturbations are triggered either by performance gaps or by proactive shifts in aspiration levels (c.f. Gilbert 2006; Greve 2008). Consider our worker attaching wheels: if the worker drops a wheel causing the task to require ten seconds longer than the routine specifies, or the worker shortens her target time for the task by ten seconds, then a perturbation has occurred. Perturbations take a process into unknown territory, where no precedents exist to guide organizational action. No one knows for certain what process should be executed next. Thus, perturbations create opportunities to explore (Nelson and Winter 1982: 156; Nonaka

1988; 1994).

Hypothesis 1. *The more perturbations, the more frequently exploration occurs.*

************** INSERT FIGURE 2 ABOUT HERE **************

Another phenomenon often associated with exploration is experimentation (Staw 1977; Thomke 2003). However, there are fundamental differences between perturbation and experimentation. A perturbation occurs when a system hitherto characterized by a stable, predictable pattern of behavior unexpectedly diverges from this equilibrium. By contrast, an experiment is “an operation carried out under controlled conditions in order to discover an unknown effect or law, to test or establish a hypothesis, or to illustrate a known law” (Webster's 1989: 437). Many experiments cause perturbations because they are designed to investigate the implications of novel and potentially disruptive stimuli on target systems. For example, crash testing a new automobile design may yield unexpected results, causing engineers to revisit there assumptions. Not all experiments cause perturbations, however. If an agent performs similar experiments repeatedly, each time yielding similar results that confirm prior knowledge, no perturbations occur. Crash testing the same automobile design for the hundredth time still constitutes an experiment, but it is unlikely to cause any perturbations. Conversely, we describe below how perturbations can occur naturally, without the existence of any experimental frame.

Perturbations can be exogenous or endogenous. Accidental perturbations, such as natural disasters, result from exogenous shocks that the organization did nothing to prompt. Induced perturbations are purposefully provoked by the organization. They may involve environmental stimuli external to the organization, as when a company launches a product in a new market and encounters unexpected problems, or they may be completely internal, as when quality circles propose changes to standard operating procedures. Induced perturbations result from unpredictable interactions between intentionally disruptive organizational actions and shifting environmental conditions. For example, reorganizations often generate perturbations as individuals with idiosyncratic knowledge are placed in different contexts, generating new ideas and communication patterns (Gulati and Puranam 2009).

Accidental perturbations occur naturally, especially in young and growing organizations. Members of the organization make mistakes or notice reverse salients and seek to address them. Disruptive stimuli enter from the environment: a customer makes an unexpected request, a supplier proposes using a different kind of component, or a piece of machinery breaks. The organization simply forgets how it responded to certain stimuli and must explore to discover a new response. These sources of accidental perturbations are severely attenuated in mature organizations. Mistakes are few and systematically corrected, obvious reverse salients have already been addressed, environmental stimuli are filtered or even blocked, and organizational memory is robust. Perturbations may be suppressed by organizational coalitions with vested interests in the status quo (c.f. Cyert & March 1963). Mature organizations settle into predictable equilibrium behavior. The more the organization exploits, the more stable the equilibrium.

Hypothesis 2. The greater the exploitation, the fewer the perturbations.

Exploration can be sustained in two ways: unintentionally, through processes of variation, selection, and retention driven by accidental exogenous perturbations (c.f. Zollo and Winter 2002); or intentionally by shaping the flow and handling of perturbations (c.f. Fuller and Stopford 1994; Teece 2007; Augier and Teece 2009). The latter approach represents the exercise of agency (Emirbayer and Mische 1998). While agency comes in many forms, here we use the term to reference conscious and intentional behaviors that alter the pattern and impact of perturbations. In mature organizations, agency plays a crucial role in sustaining exploration because accidental perturbations are scarce. Agency increases exploration through two mechanisms: deliberate perturbation and exploratory interpretation.

Deliberate perturbation are purposeful actions by an organization to augment the flow of perturbations that it experiences. Organizations can develop processes that induce perturbations, such as new product development programs or routines that rotate employees between divisions. Alternatively, organizations can construct processes to attend to and learn from accidental perturbations. Reporting systems often perform this function, as when field sales staff notify management of unexpected product failures reported by customers. Perturbations can occur anywhere in the organization, from the highest level (e.g., replacing the CEO) to the lowest (e.g., a production worker finding a defect in the product on the line or a front-line service worker receiving a customer complaint). Since mature organizations experience fewer exogenous perturbations, we predict that:

Hypothesis 3. Deliberate perturbation increases exploration in mature organizations.

Perturbations do not necessarily result in exploration. When organizations suppress perturbations and revert to previously established processes, then perturbations simply create wasteful and potentially destructive variance. Inasmuch as perturbations entail unexpected outcomes, they reveal gaps in the knowledge encoded by the organization's specialized operating routines. To learn from perturbations, organizations must respond by invoking problem-solving routines at a higher level of generality that can bridge these gaps (Argyris 1977; 1999; Tripsas 2009). From a cognitive perspective, such general-purpose meta-routines reflect on lower level routines, monitoring and analyzing operational performance to identify and learn from unexpected occurrences. This active reflection or mindful sense making helps firms take advantage of perturbations (Weick 1979; Schön 1983; Nonaka 1994). Exploratory interpretation refers to those reflective activities that invokes general-problem-solving routines in response to perturbations. When perturbations occur at a given rate, the level of exploratory interpretation governs the extent to which these perturbations translate into exploration. Conversely, an organization with a given capacity for exploratory interpretation engages in more or less exploration depending on the volume of perturbations that it experiences.

Hypothesis 4. Exploratory interpretation moderates the relationship between perturbation and exploration.

For deliberate perturbation to improve organizational performance, it must sustain efficient exploration: the long-term value of the resulting exploration must exceed the magnitude of the short-term efficiency loss. Otherwise, perturbation will simply reintroduce the destructive variance that the mature organization has labored to eliminate. For example, randomly rerouting one of every one hundred internal e-mail messages would create countless wasteful problems and distractions, but would probably not trigger any valuable innovation. The effectiveness of deliberate perturbation depends on the ability of individuals to induce and interpret perturbations judiciously. Expertise, in the form of epistemological and domain-specific knowledge, enables individuals to understand the kinds of perturbations that are likely to yield new insights and gives them the ability to extract such insights from the chaotic aftermath of the perturbation.

From the need for judgment follows the importance of commitment. Since the consequences of perturbations are inherently unpredictable and only partially visible in the short-term, organization members cannot be evaluated solely on immediate results—so doing creates a bias against exploration (Levinthal and March 1993). Where perturbations are to sustain both efficiency and exploration, organization members must be trusted—at least in the short to mid-term—with managing the tradeoff. Only individuals committed to the goals of the organization can be so trusted; others would use the freedom to pursue their own ends at the organization's expense (Gottschalg and Zollo 2007; Lewis 2009).

Perturbations must occur in all areas where the organization seeks to remain adaptive, with sufficient frequency to prevent the atrophy of explorative capabilities (Salvato 2009). This contrasts with solutions that limit risk by isolating exploration and the associated variance in separate organizational units. Broad-based adaptability across organizational processes confers two benefits: gradual performance improvements throughout the process structure as exploration yields new knowledge, and enhanced ability to handle disruptive changes as organizational processes autonomously reconfigure themselves around new equilibria (King 2000). In mature organizations, adaptability depends on deliberate perturbation and exploratory interpretation throughout the firm (e.g., Gibson and Birkinshaw 2004).

4. Efficiency and innovation at Toyota

The Toyota Motor Company illustrates how exploration coexists with exploitation. The firm has efficient, tightly controlled processes, yet it continues to innovate. Toyota builds in radical contradictions (e.g., valuing the past as well as the future) such that actors across the firm are expected to both explore as well as exploit (Osono et al. 2008). Diverse forms of deliberate perturbation and exploratory interpretation, occurring at multiple levels, sustain this balance. These activities, though diffuse and decentralized, entail agency: conscious and intentional choices of organizational actors coordinated by a sense of shared purpose. To facilitate internally coherent adaptation, actors selectively propagate perturbations in ways that trigger complementary exploration elsewhere in the organization.

Toyota uses pervasive standardization to capture and exploit its accumulated knowledge (Womack, Jones and Roos 1990; Liker 2004; Hino 2006). Individual tasks are standardized as to substance, ordering, and timing (Spear and Bowen 1999). For example, the standardized work chart for the line worker whose job includes installing the right front seat with four bolts specifies the order of the bolt installation, the torque to which the bolts should be tightened, and the time that the steps should take. Inventory is not only assigned a place on the factory floor, but a circle is painted there to mark the location and highlight encroachment. Tools have a specified place at a workstation. Material handlers follow predetermined paths through the plant. The kanban system standardizes communication pathways between process steps and specifies the structure of information exchange. Toyota standardizes and records in detail not only stable operating procedures, but also dynamic processes such as product development (Fujimoto 1999) and model changeovers. For example, in preparation for model changeovers, pilot teams create standardized work sheets for the new processes and documented procedures for the changeover (Adler et al. 1999). Toyota's commitment to standardization is significantly higher than most comparable firms (Spear and Bowen 1999; Hino 2006) and allows it to build cars twenty percent faster and at lower cost than its American competitors (Duvall 2006).

Given such intense exploitation, the Conflict School would predict Toyota to be rigid, inflexible, and devoid of exploration (c.f. Cole and Matsumiya 2007). However, the company is consistently recognized as one of the world's most innovative (McGregor 2008). At the shop-floor level, frontline workers continuously refine production processes to increase efficiency and improve quality (Hino 2006; May 2007). Higher level exploration yields innovative new brands and product categories. The LS 400, Toyota's foray into the luxury market, beat the market leaders, the Mercedes 420 SEL and BMW 735i, on five key performance criteria and was $30,000 less expensive (Dawson 2004; Liker 2004). As of 2008, the Lexus had been the best-selling luxury brand in the US for eight consecutive years (Toyota 2008). The Prius, Toyota's gasoline-electric hybrid, became "the first vehicle to provide a serious alternative to the internal combustion engine since the Stanley Steamer ran out of steam in 1924." (Taylor 2006) By mid-2007 Toyota had sold over 1,000,000 hybrid vehicles worldwide, and Prius held a greater than 40% market share in hybrid vehicles in the US in 2006 (Toyota 2007). These innovative achievements run counter to the predictions of the

Conflict School. Deliberate perturbation helps explain the anomaly.

4.1 Deliberate Perturbation at Toyota

We suggest that deliberate perturbation is necessary to sustain exploration in organizations that exploit intensively. Toyota illustrates deliberate perturbation at multiple organizational levels: individual tasks, operating systems, and business strategy. At the task level, workers frequently perturb functioning production processes by making slight changes such as inserting bolts in a different order or changing the torque applied to each bolt (Spear and Bowen 1999). One Toyota trainee reports being taught to formulate and implement modifications to shop-floor processes at a rate of more than two per hour (Spear 2004). Larger perturbations such as redesigning entire processes or relocating pieces of machinery often occur offline. For example, to shorten die changeover time for a machine press, a team of workers developed a pre-staging process and color-coded accessories (Spear 1999). Teams of workers sometimes use cardboard, LEGOs, and other everyday materials to execute dry runs of new task configurations (May 2007).

Toyota also systematically induces perturbations in operating systems—higher level processes that span entire production lines or networks of interdependent lines. Two techniques for inducing system-level perturbations are shrinking buffers between production steps and speeding up the production line. While most organizations create buffers to insulate their processes from external shocks (Thompson 1967), Toyota intentionally shrinks work-in-progress inventory buffers to induce perturbations (Ohno 1988; MacDuffie 1995). Similarly, Toyota periodically speeds up the entire assembly line, forcing workers to perform their tasks more rapidly (Mishina 1992). These techniques reduce the slack in operating systems, stressing them so that they fail in unpredictable ways, thereby perturbing associated processes.

Toyota's top management team induces high-level perturbations that can exert far-reaching influence on the firm's strategy (Fujimoto 1999; Liker 2004; Heller 2009). In 1983, Toyota's Chairman, Eiji Toyoda, asked, "Can we create a luxury car to challenge the very best?" (Dawson 2004: 5) His question set off a cascade of perturbations that eventually lead to fundamental changes to the company. After significant study and debate at the most senior levels of the company, the decision was made to enter the US luxury car market. Six years and one billion dollars later, Toyota launched the LS 400 in the US market in 1989 (Dawson 2004). The decision to enter the luxury car market began as a high-level perturbation with the top management team, but executing the strategy induced numerous perturbations at lower levels.

The development of the Lexus illustrates how perturbations can trigger high-level exploration while continuing to exploit efficient existing processes. Toyota created the processes for developing, manufacturing, and selling the new luxury automobile within its existing organization. The Lexus was designed in the same studios as other Toyota automobiles and the clay models were sculpted by the same modelers (Takagi 2007). All Lexus cars were initially manufactured within an existing Toyota plant in Japan (Dawson 2004). While Toyota made the decision to use a separate dealer network in the U.S. for marketing purposes, until 2005 the vehicle models that were sold as Lexuses in the United States were sold as Toyotas in Japan, and these models garnered around 10% of the Japanese market (Rowley 2005).

The gasoline-electric hybrid Prius provides another illustration of radical innovation resulting from a high-level perturbation induced by the top management team. In 1993, Chairman Toyoda asked his engineers to both build a new fuel-efficient car for the twenty-first century and create new product development methods. The project was assigned to the newly formed "G21" product development team. The team initially proposed a direct-injection engine that would increase fuel efficiency by fifty percent, but senior executives sent them back to the drawing board demanding a one hundred percent improvement. To achieve this demanding goal, the team bet aggressively on unproven hybrid technology. The result was the Toyota Prius, which incorporated major advances in batteries, regenerative braking, and powertrain control systems (Reinhardt, Yao and Egawa 2006).

These examples of deliberate perturbations involve actors taking direct actions to destabilize existing processes. Deliberate perturbation also occurs through the creation of systems that automatically generate streams of perturbations (Adler et al. 2009). One methodology that Toyota uses to design perturbation-inducing systems is autonomation or *jidoka*[2] (Ohno 1988; Shingo 1989). *Jidoka* describes processes that stop production automatically when faults occur, thereby generating a perturbation. The best known example of *jidoka* is the andon cord (Hino 2006). Production workers are trained to respond to problems by pulling the andon cord that runs along the assembly line. Pulling the andon cord sounds a bell and lights up a visual control board indicating the location of the problem. This attracts the attention of the team leader who responds to the perturbation by asking what has gone wrong, why the problem occurred, and how the problem can be fixed. If the problem can be resolved quickly, pulling the cord again signals that all is well and allows production to continue. Otherwise, the line segment stops automatically at the end of the cycle, generating a larger perturbation that attracts the attention of a more senior manager (Mishina 1992).

Andon pulls and line stoppages occur frequently: a worker may pull the cord a dozen times in a shift, perhaps leading to one line stoppage (Mishina 1992). Line segments within the plant are buffered so that a short stoppage in one segment has no effect on other line segments, but if the stoppage continues for a lengthy period of time, then more and more segments stop until eventually the entire plant shuts down. As more segments stop production, the perturbation cascades upward and attracts the attention of successively higher levels of the organization. The system allows low level personnel to handle the vast majority of shop floor perturbations, but ensures that perturbations that cannot be resolved at low levels cascade upward.

Exploration occurs when deliberate perturbation triggers exploratory interpretation (Schön 1983; Nonaka 1994). The structure of Toyota's processes facilitates exploratory interpretation when perturbations occur. Extensive standardization stabilizes operations so that workers more easily identify unexpected outcomes. When workers try out new ideas they are encouraged and expected to use the scientific method (Spear and Bowen 1999). Formulating testable hypotheses makes explicit the assumptions embedded in existing cognitive frames so that workers can identify contradictions between observed outcomes and the current state of their knowledge. Workers look for such contradictions even when experiments are successful; if results are better than predicted they seek to understand the reason for the deviation (Spear and

[2] *Jidoka* has the same pronunciation as the Japanese word for automation, but Toyota writes the word using a different character that emphasizes the role of human operators in the automated process, hence the translation as "autonomation."

Bowen 1999). Routines also require employees at all levels to analyze failures. When an experiment fails, employees must prepare reports that describe lessons learned and corrective actions taken (Hino 2006). These reports help others to learn from the failure and to design better experiments in the future.

Toyota's approach to shrinking buffers illustrates how operating systems and perturbations are designed to facilitate exploratory interpretation. Traditional mass production systems use work in process inventories to buffer adjacent process steps. Toyota structures adjacent process steps as standardized customer-supplier interactions through the use of kanban cards (Ohno 1988). Each interaction is associated with a specified number of kanban cards and each kanban card is associated with a specified number of parts, so the design of the kanban system sets an upper bound on the amount of inventory in flight between adjacent process steps (Spear and Bowen 1999). The system enables individuals to induce focused perturbations within single customer-supplier interactions by decreasing the number of parts per kanban or removing a kanban card from the system, thereby shrinking the buffer. When these actions cause perturbations, the detailed specification of the system's normal operating conditions helps workers uncover the origin of the perturbation and develop refinements that reduce buffers further.

4.2 Agency and efficient exploration at Toyota

We suggest that the efficiency of exploration resulting from deliberate perturbation and exploratory interpretation depends on agency. We identified three important aspects of agency: expertise, commitment, and distribution (see Figure 2). To induce highly informative perturbations in domains with comparably greater potential for performance improvement and to decode the signals carried by these perturbations, agents must be equipped with relevant expertise. To ensure that perturbations yield knowledge that contributes to high-level organizational performance, agents must be committed to shared goals. To sustain efficient and complementary cycles of exploration, agency must be widely distributed across the organization (Salvato 2009). Toyota provides illustrations of how expertise, commitment to shared goals, and broadly distributed agency support efficient exploration. From these examples, we induce hypotheses about how agency influences the dynamics of perturbation.

4.3 Expertise

Deliberate perturbation and exploratory interpretation do not necessarily improve organizational performance. While deliberate perturbation creates opportunities to invoke general-problem-solving routines, these opportunities come at the cost of disrupting the efficient, predictable operation of the organization. Exploratory interpretation triggers fruitless wandering as well as productive exploration. Since general-problem-solving routines are costly and slow, it is essential to invoke them in fertile domains with relatively high likelihood of valuable discoveries. Expertise gives agents cognitive tools to turn perturbation to the service of organizational goals.

Both domain expertise and epistemological expertise (i.e., generally applicable knowledge-acquisition techniques) influence the performance of deliberate perturbation and exploratory interpretation. Domain expertise enhances deliberate perturbation by equipping agents to induce perturbations that target general-problem-solving activity toward high-potential areas. For example, an aerodynamics engineer with clay modeling skills knows which reference points are likely to influence aerodynamic efficiency and can induce productive perturbations by instructing his or her team to focus on these areas (Liker 2004). Domain expertise also facilitates exploratory interpretation by providing better cognitive frames that enable agents to judge more accurately whether a perturbation carries a valuable signal and to structure subsequent analysis of the signal in ways that generate new knowledge (Bohn and Jaikumar 1992). Epistemological expertise facilitates both design and interpretation of perturbations by helping to structure knowledge generation processes. For example, the scientific method specifies a methodology for deliberate perturbation that enables agents to reliably generate knowledge of causal relationships.

Toyota has several techniques that help its employees acquire expertise. Intensive, on-the-job apprenticeship programs teach new employees how to induce perturbations in the context of hypothesis-driven experiments and interpret the results (Nonaka and Takeuchi 1995; Spear and Bowen 1999; Spear 1999). Spear (2004) describes the training of a successful manager who joined Toyota to run a US plant. During the training program, a Toyota expert taught the manager to induce and interpret perturbations. First, the manager spent twelve weeks observing and improving processes at a US engine plant, where he helped to formulate and implement twenty-five changes. Then the manager spent another ten days in Japan at the

Kamigo engine plant, one of Toyota's oldest and most efficient plants. At Kamigo, his teacher told him to formulate and implement fifty changes in three days, an aggressive goal that the manager met despite speaking no Japanese.

The philosophy of *genchi genbutsu* ("actual place, actual thing") emphasizes the importance of learning through first-hand experience. Toyota employees at all levels are taught to go and see problems for themselves, rather than sitting at their desks or waiting for others to provide them with the necessary information. When a factory manager calls a meeting to discuss a problem on the line, the meeting happens where the problem is occurring, not in a conference room (Mishina 1992). During the redesign of the Sienna minivan in 2004, the chief engineer sought to understand the needs of the target customer by driving in all 50 of the United States and 13 provinces of Canada. Employees are taught to observe processes with extreme care to learn how they function. For example, when training a subordinate, Taiichi Ohno, the father of the Toyota Production System, would take the employee to a part of the plant, draw a circle on the floor, and tell the employee to stand inside the circle and watch the process (Ohno 1988). This would often last for an entire day (Liker 2004).

Toyota invests heavily in capturing and diffusing expertise. Employees are trained to record lessons learned and to consult these written records when a problem occurs (Sobek, Liker and Ward 1998). Expertise is captured explicitly in the form of written standards which propagate laterally across the organization as employees consult and conform to the standards, a process Toyota terms *yokoten*. To transfer expertise to its overseas sites, Toyota frequently brings engineers, managers, production workers, and supplier representatives to Japan to study its operations. When launching new plants, Toyota often sends expert employees from existing facilities to spend several months training the workforce through both classroom and on-the-job training (Mishina 1992; Adler et al. 1999; Fujimoto 1999).

The expertise of Toyota employees enables them to induce and interpret perturbations rapidly. Perturbations increase the potential for exploration (see hypothesis 1). To realize this potential, however, organizations must detect, interpret, and learn from the perturbations. The capacity of an organization to perform these functions is limited. Perturbations become destructive when they occur too frequently: the organization experiences costly disturbances, but fails to capture the resulting opportunities for exploration. Expertise increases the rate at which organizations can induce and respond to perturbations through several mechanisms. First, agents equipped with expertise about their problem-solving domain and the knowledge-generation process can recognize areas where perturbations are likely to trigger productive exploration. Second, expert agents can induce more meaningful perturbations that are easier to detect and interpret. Third, expertise facilitates rapid and accurate interpretation of perturbations, enabling efficiently targeted application of exploratory routines. The discussion above illustrates how expertise informs the induction and interpretation of perturbations.

Hypothesis 5. *The greater the expertise of agents, the greater the effectiveness of deliberate perturbation and exploratory interpretation.*

4.4 Commitment

Deliberate perturbation and exploratory interpretation require the commitment of organization members to function effectively. Commitment describes the degree to which organizational agents identify with and take initiative to advance shared organizational goals (Simon 1981: 43). Individuals cannot engage in deliberate perturbation and exploratory interpretation automatically, because perturbations entail deviating from established routines. Organization members must possess the commitment to engage actively and autonomously in the creation of new knowledge through inducing perturbations and reflecting on their effects. Furthermore, unless commitment is directed toward shared goals, deliberate perturbation and exploratory interpretation will be uncoordinated at best and counterproductive at worst (c.f. Gottschalg and Zollo 2007).

Toyota managers, beginning with the founders, have worked to inculcate a widely held commitment to continuous improvement in pursuit of seemingly-impossible goals such as the total elimination of waste (Spear and Bowen 1999; Osono et al. 2008). To the extent that these goals cannot be achieved by exploiting the organization’s existing routines, they encourage and sanction employees to induce perturbations (c.f. Winter 2000). Since the outcomes of perturbations are inherently risky, the organization must recognize failure as a natural and acceptable aspect of growth. According to a former Toyota executive, “Toyota’s top managers berate people who don’t try to come up with new ideas or who don’t take up new challenges, but not people who try something and fail. The role of senior managers is … to help subordinates with new ideas or challenges … That's what makes trial and error possible" (Hino 2006: 91-92). Employees are trained to view failures as opportunities to learn, rather than as threats to the stable execution of their existing work (Sitkin 1992; Fujimoto 1999; Gilbert 2006).

The development of the Lexus engine provides an illustration of the relationship between commitment and deliberate perturbation. After substantial development effort, the Lexus team had designed and tested a 3.8-liter V-8 engine that nearly met the project's performance goals. Worried that competitors' cars under development might offer better performance than the new Lexus, the project manager literally tore up the blueprints and sent his team back to the drawing board to develop a 4.0-liter engine. When the decision met substantial resistance from the Lexus team, the project manager went back up the management hierarchy for assistance. Toyota's head of engine development let it be known that top management supported the project manager's judgment and expected the task to be accomplished (Dawson 2004). Though the Lexus project was successful, the wisdom of this particular perturbation cannot be evaluated with any certainty; however, it clearly shows how the commitment of the project manager and senior management to aggressive goals contributed to deliberate perturbation.

The commitment of Toyota employees to continuous improvement causes them to respond to even minor perturbations with exploratory interpretation, rather than stubbornly reverting to established processes. This phenomenon is illustrated by the "five why's" routine. Employees at all levels are trained to respond to unexpected occurrences by asking "why?" repeatedly until the root cause of a problem is identified and potential solutions are generated (Mishina 1992). For example, if a worker notices a puddle of oil on the floor at Toyota he or she does not just wipe it up and move on, but asks what caused the puddle. Many organizations forego opportunities to learn by making do with superficial solutions instead of addressing root causes (Tucker 2004). The five why's routine illustrates the complementarity of expertise and commitment: both are necessary to go beyond superficial reflection.

To prevent deliberate perturbation and exploratory interpretation from becoming wasteful or counterproductive, they must be oriented toward shared goals. Two prominent shared goals at Toyota are customer and dealer satisfaction, as captured by the Toyota slogan "customer first, dealers second, and manufacturer last" that privileges the welfare of customers and dealers over that of the firm itself (Osono et al. 2008: 121). For example, shortly after the Lexus launch, the cruise control on a LS 400 failed during a test drive, causing the car to accelerate unexpectedly (Dawson 2004). When a salesman at the San Diego dealership reported the problem to the service hotline, the organization propagated the perturbation broadly, triggering problem-solving activity across multiple organizational units. Subsequent exploration determined the cause of the problem—a faulty actuator switch—and formulated a response to satisfy demanding luxury car owners—all cars were picked up, repaired, refueled, washed, and returned (Gwynne and Kanise 1990). Osono et al. (2008) report that "For customers in Alaska, personnel from the nearest area office made house calls by plane to make the repairs" (138). The repairs were undertaken more rapidly than typical automobile recalls, Toyota bore all costs, and dealers were impressed by Toyota's handling of the problem (Osono et al. 2008)[3]. Other shared goals that orient deliberate perturbation and exploratory interpretation include elimination of waste and continuous improvement (Liker 2004).

Hypothesis 6. *The greater the commitment of agents, the greater the effectiveness of deliberate perturbation and exploratory interpretation.*

4.5 Distribution

Broad-based agency contributes to efficient, coordinated exploration. Since formulating and interpreting perturbations consumes attention, the capacity of an organization to leverage deliberate perturbation into efficient exploration increases with the exercise of agency by expert, committed organization members (Simon 1947; March and Simon 1993; Ocasio 1997). By enabling the organization to autonomously reconfigure itself, broad-based agency facilitates radical strategic change (Agarwal and Helfat 2009). Successful completion of strategic change requires sustained, coordinated exploration across multiple levels and functions. Widely distributed agency helps drive such coordinated exploration because many agents throughout the organization interpret and selectively cascade perturbations on the basis of shared goals (see also, Bartlett and Ghoshal 1989; O'Reilly and Pfeffer 2000).

[3] Toyota's recent handling of similar problems has been widely criticized as slow, confused and reactive (Vlasic 2010).

Toyota illustrates how broad-based agency leverages the attention of employees to drive efficient exploration (Ohno 1988; Liker 2004). An important tenet of Toyota's philosophy is to delegate authority and responsibility for recognizing and solving problems to the lowest possible level in the organization (Spear and Bowen 1999). As opposed to assigning responsibility for process improvement to a relatively small number of designated industrial engineers, the traditional approach of Western automobile companies, Toyota effectively turns every factory floor worker into an applied industrial engineer (Kaneda and Kondo 2007). Workers at all levels engage in deliberate perturbation, from modifying single assembly tasks to launching new product initiatives

Deliberate perturbation at intermediate levels of the organization is particularly difficult, since mid-level managers are constrained from above by strategic pressures and from below by operational realities (c.f. Taylor and Helfat 2009). The creation of the Scion brand illustrates mid-level deliberate perturbation. Concerned about the company's aging customer profile, executives created a marketing team in the USA tasked with promoting three new Toyota models among younger buyers (Lee, Peleg and Whang 2005). The group tried out new marketing techniques and the cars sold well, but attracted little interest from younger customers. After analyzing sales results and customer surveys, the group concluded that more dramatic changes were necessary. They resolved to create a new, edgy, low-price brand called Scion. The group identified two existing Toyota models sold only in Japan, rebadged them with the Scion marque, and made minor design changes. The project induced additional perturbations by adopting fixed price selling, offering online ordering and accessorizing, creating after-market accessorizing partnerships, and using word of mouth advertising. Also, the project sought to exploit Toyota's flexible manufacturing operations by trying out a four year product lifecycle expected to appeal to Scion's trend-setting customer base (Vasilash 2003). Manufacturing and product development for the Scion brand was left integrated within Toyota and, in contrast to Lexus, so too was the American dealer network. However, existing dealers who wanted to offer the Scion brand were required to create a separate showroom staffed with new salespeople at a cost of around $120,000 (Palmeri, Elgin and Kerwin 2003; Lee et al. 2005). By 2006 Scion made up almost 7% of Toyota's US sales (Taylor 2007) and had the youngest average age of any automotive brand (Vasilash 2007).

Broadly distributed agency also facilitates radical strategic change. To be effective, radical change requires many complementary adjustments in processes throughout the organization (Anderson and Tushman 1990; Henderson and Clark 1990). When a high-level perturbation occurs, agents drive coordinated and far-reaching exploration by selectively cascading perturbations outward through the organization's process space. Broad-based agency facilitates radical change because organization members detect high level perturbations autonomously and judge whether to inducing complementary perturbations locally (Burgelman 1991; Nonaka 1994). Since relevant information is distributed across the organization's process space, the presence of committed agents with expertise and decision-making authority enables the organization to reconfigure semi-autonomously around a new and potentially very different equilibrium (Hayek 1945). Such deep flexibility helps organizations survive through major environmental shifts.

The development of the Lexus illustrates how broad-based agency supports high-level exploration. As with most product development initiatives at Toyota, the task was assigned to a heavyweight project manager. While Toyota was organized functionally, the heavyweight project manager not only led engineers from across departments, but also owned the product concept (Clark and Fujimoto 1991). Ichiro Suzuki, the project manager who led the bulk of the Lexus development, did not have formal authority over all of his subordinates, but due to his prior accomplishments at the company, "All he had to do was snap his fingers and his men would come running (Dawson 2004: 46)." In keeping with Toyota's philosophy (Hino 2006; Osono et al. 2008), Suzuki set aggressive goals for the project. Suzuki determined that the new car should exceed the performance of the market-leading BMW 7 series and Mercedes S class on aerodynamics, fuel efficiency, maximum speed, quietness, and weight. Rather than simply benchmarking against competing models, the team took apart many luxury cars and benchmarked against the best individual parts. His motto was *naokatsu*, which translates as "never, ever, compromise" (Dawson 2004: 45). Members of Suzuki's own team feared that his objectives could be met only by a limited production, custom vehicle (Dawson 2004); however, these aggressive goals encouraged team members to interpret perturbations by searching for superior new technologies instead of falling back on proven but mediocre knowledge.

The development of the car's drivetrain, the car's most expensive subsystem, shows how deliberate perturbation and broad-based agency yield coordinated, complementary exploration. At the time, Toyota was known for its competency building inline engines and all mass-produced Toyota models had four or six cylinder inline engines. For the Lexus, Suzuki's predecessor decided that not only must the new car's engine have eight cylinders, for power and marketing purposes it needed to be a V-8 (Dawson 2004). In a V-8 engine the cylinders are configured in a V rather than a line, so this decision meant that the design team could not rely on its deep experience and competence with inline engines (c.f. Tushman and Anderson 1986). The final engine included many complementary innovations that helped achieve the car's overall performance targets, such as putting the starter motor inside the V to conserve space and reduce noise, and powering the cooling fan with oil pressure instead of a battery to conserve power and weight.

Many drivetrain innovations were made possible by Toyota's sophisticated operational capabilities. For example, the company's precise manufacturing capabilities enabled the designers to reduce the space between engine parts by one third. The Lexus also incorporated a straight driveshaft, in contrast to most competing rear-wheel-drive luxury cars that used angled driveshafts to transmit power from the gearbox to the rear differential. The angle increases noise and wastes power, but is used because of the extreme difficultly involved in manufacturing an entirely straight driveshaft. Suzuki's team was able to design an innovative straight driveshaft and then rely on the firm's sophisticated manufacturing capabilities to reliably produce the part (Dawson 2004).

Hypothesis 7. *The broader the distribution of agency, the greater the effectiveness of deliberate perturbation and exploratory interpretation.*

5. Implications

For several decades Toyota has used deliberate perturbation and exploratory interpretation to sustain a complementary and highly successful synthesis of exploration and exploitation. Toyota's high level of maturity does not hinder exploration. On the contrary, the firm's focus on control and process improvement creates a robust foundation for selectively inducing and learning from perturbations. This synthesis is not achieved by separate structures dedicated to exploration and exploitation bound together by agency concentrated at the top of the organization (O'Reilly and Tushman 2008). On the contrary, individuals at all levels of the organization actively manage the tension between exploration and exploitation (Gibson and Birkinshaw 2004). Toyota employees frame breakdowns in established routines as opportunities to explore and learn, rather than as threats to be suppressed (see Gilbert 2006). Apparent tradeoffs and paradoxes are used to inspire introspection and improvisation, not taken for granted as immutable constraints (Adler et al. 2009). Toyota's example suggests that perturbation may be an essential mechanism through which dynamic capabilities enable exploration and exploitation to coexist (Teece et al. 1997; Helfat et al. 2007; Capron and Mitchell 2009).

Drawing on examples from Toyota, our model predicts that long-term organizational performance will benefit from broad participation of organization members in the induction and interpretation of perturbations (c.f. Nonaka 1994; Ghoshal and Bartlett 1997; Garvin, Edmondson and Gino 2008). To secure such broad participation, management must trust employees to perturb processes, help them acquire the expertise necessary to detect and interpret perturbations, and instill in them the commitment to do so. Supervisors cannot see inside the mind of an employee in an Ohno circle: an uncommitted employee could simply enjoy a four-hour break from work. Similarly, the andon cord system requires a widely shared commitment to calling attention to and learning from problems: organizations that focus on short-term efficiency metrics such as minimizing line stoppages have been known to discourage employees from pulling the andon cords, and then interpret the lack of pulls as a sign of success (Liker 2004). Sustaining exploration in mature organizations depends on the commitment and expertise of frontline employees as well as on strategic decision-making by senior management (c.f. O'Reilly and Pfeffer 2000).

Agency helps determine whether organizations should use contextual or structural ambidexterity (Gibson and Birkinshaw 2004; O'Reilly and Tushman 2008). When commitment and expertise reside only in the top management team, then employees at lower levels cannot be relied upon to judiciously balance exploration and exploitation. Under such circumstances, structural ambidexterity—isolating exploration and exploitation in separate organizational units—may be the only path to long-term viability. Conversely, when agents throughout the organization are devoted to shared organizational goals and equipped with the expertise required to induce and learn from perturbations, tight integration of exploration and exploitation along the lines envisioned by theorists of contextual ambidexterity may be achievable. Furthermore, such diffusion of agency enables organization members to understand and autonomously reconfigure themselves in response to high-level perturbations, facilitating strategic change and radical innovation.

Our focus on agency emphasizes the endogeneity of problems and problem solving. This contrasts with the traditional information processing view of organizations (Simon 1947; Galbraith 1974; Tushman and Nadler 1978; March and Simon 1993). In place of mechanical routine execution, our model posits networks of purposeful agents engaged in frequent but highly selective perturbation and interpretation, even as they adhere strictly to established standards. Our model thus addresses a weakness of the information processing view that Nonaka (1994) characterizes as "a passive and static view of the organization." (p. 14) The information processing view tends to see organizations as symbol manipulators, not as living organisms that learn and grow (Nonaka 1994). The information processing view emphasizes the execution of existing procedures, while largely ignoring how organizations explore. This is perhaps unsurprising, given that the focal insight of the Carnegie School was how organizations economize the limited information processing capacity of the human mind. Our theory foregrounds questions about how organization members induce and interpret perturbations, and how perturbations propagate through the organization. Efficient exploration depends on interpreting the signals carried by perturbations, and creating or reconfiguring processes based on those interpretations (c.f. Daft and Weick 1984).

6. Conclusion

Prior theoretical and empirical literature diverges as to whether exploitation undermines or supports exploration. The divergence reflects a gap: the missing mechanism by which organizations break free of old routines and discover new ones. We propose that the mechanism is perturbation, and that organizations can deliberately perturb themselves in order to stimulate exploration (c.f. Langton 1990). Based on a model of organizational activity as hierarchically nested processes, we suggest that intense exploitation creates a stable environment for inducing, interpreting, and learning from perturbations. Toyota illustrates the feasibility of this technique, and its potential to yield superior performance over an extended period of time. At the same time, Toyota's recent challenges highlight the difficulty of sustaining robust capabilities for deliberate perturbation and exploratory interpretation (Vlasic 2010). Our inquiry leads to a conception of the learning organization as one where purposeful agents at once provoke streams of cascading perturbations and use these signal-laden disruptions to propel themselves beyond the established bounds of the possible.

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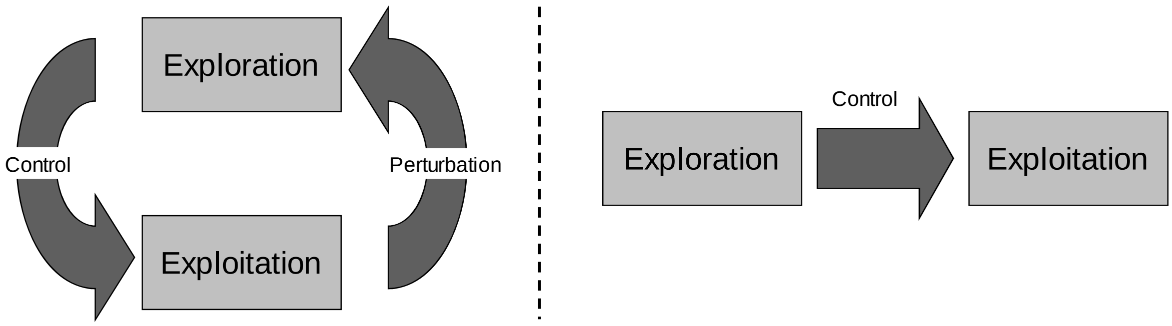
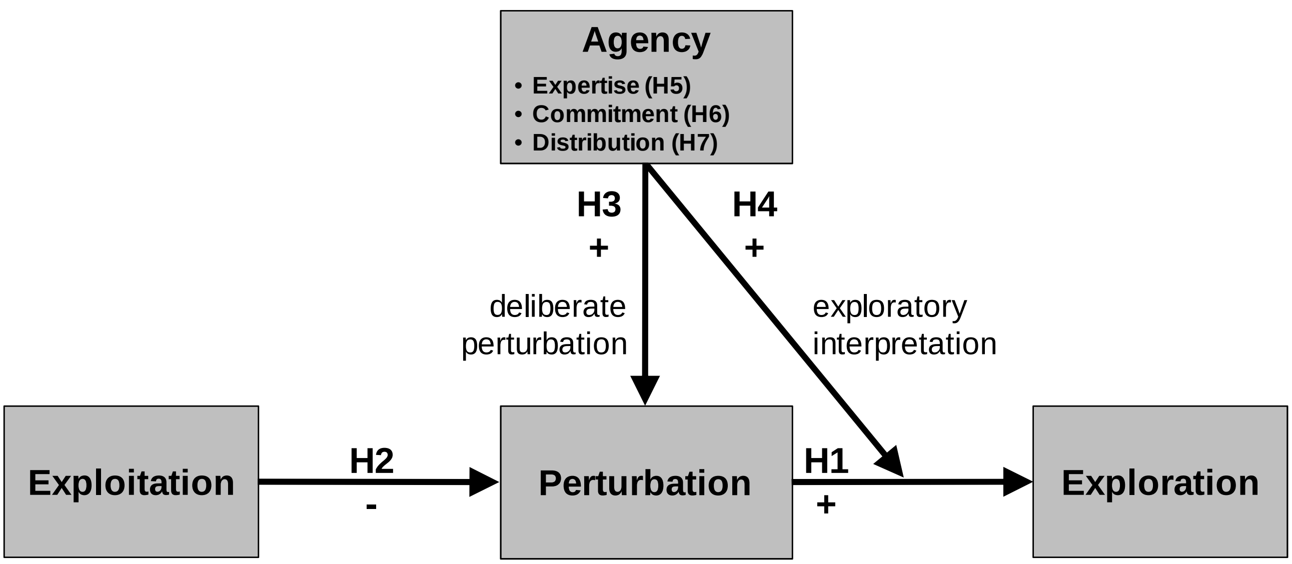
FIGURE 1



Models of the relationship between exploration and exploitation. In our proposed model (left), perturbation leads organizations back to exploration. Without perturbations, our model reduces to the established model (right) where control results in exploitation gradually driving out exploration.

FIGURE 2



Perturbations are necessary, but not sufficient for moving from exploitation to exploration,, while agency influences both the flow of perturbations experienced by the organization and the nature of the resulting exploration. The more mature the organization, the more crucial the role of agency.