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FAILING TO LEARN? THE EFFECTS OF FAILURE AND SUCCESS ON ORGANIZATIONAL LEARNING IN THE GLOBAL ORBITAL LAUNCH VEHICLE INDUSTRY

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It is unclear whether the common finding of improved organizational performance with increasing organizational experience is driven by learning from success, learning from failure, or some combination of the two. We disaggregate these types of experience and address their relative (and interactive) effects on organizational performance in the orbital launch vehicle industry. We find that organizations learn more effectively from failures than successes, that knowledge from failure depreciates more slowly than knowledge from success, and that prior stocks of experience and the magnitude of failure influence how effectively organizations can learn from various forms of experience.

On the morning of January 16, 2003, the *Columbia* lifted off from John F. Kennedy Space Center in the National Aeronautics and Space Administration's (NASA's) 113th space shuttle launch. Eighty-two seconds into the launch, a piece of foam insulation broke free from the left bipod ramp area of the shuttle's external fuel tank and struck the leading edge of *Columbia's* left wing. As the orbiter reentered earth's atmosphere at the conclusion of its 16-day mission, damage sustained from the foam's impact compromised the orbiter's thermal protection system, leading to the failure of the left wing and to the eventual disintegration of the orbiter. None of *Columbia*'s crew of seven survived.

Within minutes of the break-up, the NASA Mishap Investigation Team was activated; within two hours, the Columbia Accident Investigation Board (CAIB) was established to "discover the conditions that produced this tragic outcome and to share those lessons in such a way that this nation's space program will emerge stronger and more sure-footed" (CAIB, 2003: 6). The 13 members of the board, assisted by a staff of more than 120, "examined more than 30,000 documents, conducted more than 200 formal interviews, heard testimony from dozens of expert witnesses, and reviewed more than 3,000 inputs from the general public" (CAIB, 2003: 9). Seven months after *Columbia's* demise, CAIB issued a six-volume, 4,000-page report on the findings of its investigation. The *CAIB Report* included 29 specific recommended changes that NASA should undertake prior to the space shuttle's return to flight. The space shuttle program was suspended during the duration of the CAIB investigation and the time required by NASA to implement many of the CAIB recommendations. The space shuttle returned to flight with the launch of *Discovery* on July 26, 2005.

The massive CAIB investigation stands in stark contrast to the minimal investigation that followed a similar loss of foam insulation from the left bipod ramp during the launch of the *Atlantis* on October 7, 2002 (the 111th shuttle launch). Thirty-three seconds into the ascent, foam from the left bipod ramp broke free, impacting and damaging a ring holding the shuttle's left solid rocket booster to the external fuel tank (CAIB, 2003). The damage did not interfere with the launch and did not prevent the safe return of the *Atlantis* orbiter. The foam loss and resulting damage were addressed after the return of *Atlantis* in a NASA Program Requirements Control Board meeting in which it was determined that investigation of the cause of the foam loss was not a serious enough issue to warrant delays of future shuttle launches (CAIB, 2003). The investigation into the incident had not been completed by the time of *Columbia*'s launch.

The *CAIB Report* notes that despite significant similarity between the foam loss events experienced during the two launches, one dissimilarity explains the vast difference in NASA's responses to them and attempts to learn from them: the *Atlantis* mission was viewed as a success, the *Columbia* mission, as a catastrophic failure. Indeed, a major theme of the report is the CAIB's view of the effect of NASA's prior success and failure experiences on its organizational learning. The board argued that NASA's long history of success in the shuttle program contributed to the *Columbia* accident by artificially inflating NASA managers' confidence in their ability to manage the risks of human space flight (the risk of external tank foam loss, in particular). According to the CAIB, "It seems that Shuttle managers had become conditioned over time to not regard foam loss or debris as a safety-of-flight concern" (2003: 125). On the other hand, the report expresses optimism about how the board was able to uncover the causes of the *Columbia* disaster and states that NASA would learn to prevent future accidents (resulting from foam losses as well as from other causes) via CAIB recommendations.

The CAIB's view of the importance of prior failures (relative to prior successes) in driving organizational learning mirrors the arguments of organizational learning theory. Organizational learning theorists have long held that organizations learn primarily through processes of "problemistic search" that they engage in only after experiencing failures (Cyert & March, 1963; Lant, 1992; March & Shapira, 1992). This being the case, the common empirical finding of improvement in organizational performance through learning from experience is argued to obtain only because greater organizational experience provides greater opportunity for organizational failure (Sitkin, 1992). However, existing evidence that failure is more important than success for organizational learning is entirely anecdotal (Cannon & Edmondson, 2001; Tax & Brown, 1998). Indeed, no direct empirical examination of the relative efficacy of organizational learning from success and failure exists in the organizational learning literature.

The purpose of the present study was to fill this gap by disaggregating organizational experience into failure experience and success experience and comparing the contribution of each to organizational performance. In essence, we attempted to determine whether the common finding of improved organizational outcomes with increasing organizational experience is driven by learning from success, learning from failure, or some combination of the two.

Additionally, we also extend prior theory on organizational learning from success and failure in three directions. First, we develop theory regarding why knowledge derived through success experience and knowledge derived through failure experience depreciate at different rates. This is an important contribution, given that the theoretical mechanisms behind knowledge depreciation have received scant attention in prior work (for exceptions, see de Holan and Phillips [2004] and Thompson [2007]). Second, in contrast with prior authors (e.g., Sitkin, 1992), we hypothesize that organizations learn more effectively from large failures than from small failures. Third, we argue that vicarious organizational learning occurs more effectively through observation of others' failures than through observation of others' successes, but that the process of vicarious learning from failure depends critically on direct learning from failure. This argument advances the theoretical literature on organizational learning by addressing how various forms of organizational experience may interactively influence learning processes (see also Baum & Dahlin, 2007). We also identify related boundary conditions on organizations' abilities to learn from successes and failures. We explore these issues in the context of the global orbital launch vehicle industry from its inception in 1957 through March 2004.

THEORY AND HYPOTHESES

Organizational Knowledge and Organizational Learning

Organizational learning theory contributes to a larger theoretical movement emphasizing the importance of knowledge development and knowledge storage in organizations, which also includes evolutionary economics, the knowledge-based theory of the firm, and theory on organizational memory, group learning, and shared cognition (Grant, 1996; Kogut & Zander, 1996; Nelson & Winter, 1982; Walsh & Ungson, 1991; Weick, 1979). In these literatures, organizational knowledge is seen as the set of expectations and assumptions held by an organization's members about the cause-and-effect linkages in their domains of activity (Huber, 1991; Walsh & Ungson, 1991). In essence, organizational knowledge is an organization's internal representation of the world (Daft & Weick, 1984). An organization's knowledge determines what actions its members are capable of taking, as well as how they coordinate and integrate their efforts.

Many conceptualizations have emphasized that an organization's knowledge resides at the organizational level, is separate and distinct from the knowledge of individual organization members, and is not lost when individuals leave the organization (Adler, 2001; de Holan & Phillips, 2004; Eisenhardt & Martin, 2000; Levitt & March, 1988; Nelson & Winter, 1982). But recent work has indicated that the knowledge that drives organizational performance is an amalgam of both individual and collective memory systems (Anand, Manz, & Glick, 1998; Felin & Hesterly, 2007; Groysberg, Lee, &

Nanda, 2008; Huckman & Pisano, 2006). From this perspective, organizational knowledge must be seen as encompassing codified, procedural knowledge embodied in organizational goals, routines, standard operating procedures and rules, and tacit, noncodified knowledge embodied in collective cognitions such as shared mental models, transactive memory systems, and organizational culture, as well as in individual cognitions and memories (Conner, 1991; Grant, 1996; March & Olsen, 1976; Nelson & Winter, 1982; Simon, 1991; Wegner, 1986; Weick & Roberts, 1993). Knowledge belongs exclusively to neither organization nor individual, but to both simultaneously.

Furthermore, organizational knowledge is not static; it is created, refined, altered, and discarded as organization members experience reality and attempt to update their individual and shared understandings of it to reflect the lessons they draw from their experience (Cyert & March, 1963; Huber, 1991; Levitt & March, 1988). Organization members encode the lessons they extract from experience through altering their own cognitive frames; through altering formal organizational structures, roles, rewards, rules, or standard operating procedures; and through altering stores of informal organizational assumptions embodied in stories, rituals, rites, and relationships (March, 1981; Schein, 1985).

Building on this view of organizational knowledge and knowledge development, we define organizational learning as any modification of an organization's knowledge occurring as a result of its experience. Given the difficulty of observing changes in organizational knowledge itself, the assumption in much of the empirical organizational learning literature is that changes in observable organizational performance reflect changes in organizational knowledge (see Argote, 1999; Baum & Ingram, 1998). We adopt this convention and operationally define organizational learning as a modification in organizational performance as a result of experience. Consequently, an organization will be said to have learned from prior experience to the extent that the experience is associated with an observed change in organizational performance.

Three key conditions must be met before prior organizational experience can be expected to influence observed organizational performance: prior experience must motivate organization members to alter organizational knowledge; organization members must be able to extract meaningful new knowledge from experience; and the changes made to organizational knowledge must alter the subsequent behavior of organization members. Our theoretical discussion in the following sections focuses primarily on the first two conditions, leaving implicit the assumption that organizational knowledge impacts behavior.

Learning from Success and Failure

Although the bulk of prior empirical organizational learning research has examined learning from aggregated organizational experience (Argote & Epple, 1990; Darr, Argote, & Epple, 1995; Ingram & Baum, 1997; Rapping, 1965), recent work has begun to explore organizational learning from prior failure experience, disaggregated from total prior experience (Baum & Ingram, 1998; Haunschild & Sullivan, 2002; Miner, Kim, Holzinger, & Haunschild, 1999). Organizational learning theories borrow from the behavioral theory of the firm (Cyert & March, 1963)—the notion that organizational decision makers' attention is aspiration oriented—with aspirations defined as the lowest level of performance that organizational decision makers consider acceptable (Greve, 2003). Aspirations serve to dichotomize organizational performance into success and failure; decision makers define performance that exceeds some relevant aspiration level as success and define performance that falls below the aspiration level as failure (Cyert & March, 1963; March & Simon, 1958).

According to the behavioral theory of the firm, organizational decision makers respond quite differently to failure than they do to success. Decision makers interpret success experience as evidence that existing organizational knowledge represents the world well and that further (usually costly) development of knowledge is unnecessary (Lant, 1992; March & Shapira, 1992; Ross & Sicoly, 1979). As a result, prior successes induce organizational decision makers to ignore information about the outside world and to simplify their decision-making approaches (Audia, Locke, & Smith, 2000; Hayward, Rindova, & Pollock, 2004). Prior success also leads decision makers to be overconfident about the adequacy of their existing knowledge (Louis & Sutton, 1991). Although success does not lead organization members to entirely cease processing new information, it directs their attention to local information sources, those that are in the vicinity of current organizational knowledge, and discourages "nonlocal search" (Cyert & March, 1963; March, 1981). "Local search," in turn, prompts organization members to refine their existing assumptions and approaches, but not to challenge them (Lant, 1992; Weick, 1984).

On the other hand, while organizational success leads to stability in organizational knowledge, failure challenges it. Because failure experience indicates to organization members that their existing models of the world are inadequate, failure motivates them to discard those models in a search for new models that better represent reality (Cyert & March, 1963; March & Simon, 1958). Furthermore, because failure challenges the status quo, it induces decision makers to engage in deep or mindful reflection involving complex thought processes (Langer, 1989; Morris & Moore, 2000; Weick & Roberts, 1993). Organizational search for knowledge in response to failure, or problemistic search, is associated with a sense of urgency that is lacking in other forms of organizational search and is, therefore, more likely to lead to the adoption of new and divergent ideas (Cameron, 1984; March, 1981). Failure motivates organization members to correct problems, challenge old assumptions, and innovate (Sitkin, 1992).

Furthermore, failure indicates not only the existence of a gap in organizational knowledge, but in many cases also provides a clear indication of where that gap may be (Turner, 1978; Wildavsky, 1988). Therefore, failure not only increases organization members' willingness to search for new knowledge, but also provides a roadmap showing where search activities may be most productive (Levinthal & March, 1981). Any organizational search initiated following success faces much greater uncertainty. In other words, experience with failure is more likely than experience with success to produce two of the necessary conditions for experiential learning discussed above: the motivation to alter knowledge, and ability to extract meaningful knowledge from experience.

This view of organizational learning from success and failure lines up well with the CAIB's assessment of NASA's learning from its successful and failed space shuttle launch experience. A long history of successful launches taught NASA personnel that the organization's existing knowledge represented the challenges of human spaceflight well and prompted a marked decrease in the search for new knowledge (Vaughan, 1996, 2005). Even clearly anomalous events (such as external fuel tank foam losses) occurring during successful launches failed to challenge the status quo, leading NASA decision makers to "flawed decision making, self deception, introversion, and a diminished curiosity about the world" (CAIB, 2003: 102). But a visible failure clearly exposed gaps in NASA's knowledge of shuttle safety and prompted a massive rethinking of that knowledge.

Despite strong theoretical arguments, as well as anecdotal evidence, that organizations learn more from past failures than from past successes, the relative efficacy of organizational learning from success and failure has not been studied directly and empirically. Indeed, none of the few extant empirical studies of organizational learning from failure has directly compared learning from failure with learning from success (Baum & Dahlin, 2007; Haunschild & Rhee, 2004; Haunschild & Sullivan, 2002).

For example, Haunschild and Sullivan (2002) investigated the effect of prior organizational accident experience on future accident rates among large U.S. airlines, controlling for prior airline operating experience by entering airline age as a control variable. They found that prior accident experience did indeed reduce the rates of future accidents and that older airlines were less likely to experience accidents than were younger airlines. However, with failures measured as a count variable, and age serving as a proxy for other (successful) experience, direct comparison of learning from success and failure within their results is not possible. Similarly, Haunschild and Rhee (2004) examined the effect of prior automobile recalls on the likelihood of future recalls, finding that previous experience with voluntary recalls decreased an automaker's chance of experiencing future involuntary recalls, but that prior experience with involuntary recalls did not significantly affect rates of future involuntary recalls. These authors found that the effect of prior automobile production experience (a proxy for prior success experience) on future recall rates was negative (indicating learning), but rarely statistically significant. Again, differences in units—automobiles versus recall count—makes direct comparison of learning from success and failure impossible.

Baum and Dahlin (2007) have provided the most direct existing comparison of organizational learning from success and failure. They studied the effects of prior operating experience and accident costs on future accident costs among large U.S. railroads. In their full models, these authors found a negative main effect of prior operating experience on future accident costs, but an insignificant main effect of past accident costs on future accident costs, suggesting learning from success and not from failure. But Baum and Dahlin also considered that learning from experience might be contingent on current organizational performance, finding that current railroad accident costs decreased with both prior operating performance and prior accident costs when a railroad was performing below its current aspirations, but increased with both when it was performing above its aspirations. These results suggest that organizations may learn (improve performance) from prior success and failure under some conditions, but not under all conditions.

However, with prior accident costs measured in dollars and prior operating experience in train miles traveled, direct comparison of learning from success and failure was not feasible.

The noted difficulty of comparing learning from success and failure is certainly not an indictment of these three important studies of learning from organizational failure. None of them was intended as such a comparison. As the current work is so intended, we propose a direct comparison of organizational learning from prior success and failure:

Hypothesis 1. Prior organizational failure experience reduces the likelihood of future organizational failure more than does prior organizational success experience.

Vicarious Learning from Success and Failure

Organizational learning theory suggests that organization members develop knowledge not only through their direct experience, but also vicariously, through observation of the experience of other organizations (Beckman & Haunschild, 2002; Denrell, 2003; Haunschild & Miner, 1997; Ingram & Baum, 1997; Miner & Haunschild, 1995). Members of an organization rarely have direct access to other organizations' stores of knowledge. But others' expectations about current and future states of the world (and consequently, these others' cause-and-effect assumptions) can often be inferred from their actions (Abrahamson, 1996; Bikhchandani, Hirshleifer, & Welch, 1992; Strang & Macy, 2001). A focal organization's knowledge may be enriched through such inference to the extent that others' knowledge is based on bodies of experience that are greater than, or simply different from, its own (Anderson & Holt, 1997; Miner et al., 1999). Although learning vicariously through inference may, in some cases, produce faddish learning that induces decision makers to adopt valueless practices (Abrahamson & Fairchild, 1999; Davis, 1991), the general strategy of social learning enhances performance by introducing new organizational knowledge (Beckman & Haunschild, 2002; Bikhchandani et al., 1992).

Although most work on vicarious organizational learning considers learning from others' aggregate prior experience, a nascent body of research focuses on organizational learning from others' failures (Chuang & Baum, 2003; Kim, 2000; Miner et al., 1999). Indeed, there is significant empirical evidence that the likelihood of organizational failure decreases as the number of failures experienced by other, similar organizations increases (Baum & Dahlin, 2007; Chuang & Baum, 2003; Haunschild & Sullivan, 2002; Ingram & Baum, 1997; Kim & Miner, 2007).

We are not aware of any extant work that examines vicarious organizational learning from the successes of others or that hypothesizes the relative efficacy of vicarious organizational learning from success and failure, respectively. For several reasons, we propose that organizations learn more from observing others' failures than others' successes. First, populations of organizations operating in a common domain typically employ very similar organizational forms and sets of practices and routines (Hannan & Carroll, 1992; Miner et al., 1999). Because the knowledge bases held by different organizations in a domain are similar, observations of vicarious success and failure may produce reactions similar to those produced by direct success and failure experience. Specifically, observing others' successes may increase decision makers' confidence in the accuracy of knowledge held by their own organization and, consequently, lead them to reduce search activities (Wildavsky, 1988). Alternately, observing others' failures may lead decision makers to question their own knowledge and to intensify search activities (Baum & Dahlin, 2007; Miner et al., 1999).

Second, knowledge held by other organizations may become more accessible following failures than following successes. Members of successful organizations tightly guard knowledge that they perceive to have produced success (Anton & Yao, 2004; Katila, Rosenberger, & Eisenhardt, 2008). Indeed, in many industries, secrecy is considered a better protection for proprietary knowledge than formal intellectual property mechanisms such as patents (Arundel, 2001). On the other hand, failure often induces (or forces) organization members to make their knowledge public. They may be willing to reveal to others the previous, flawed knowledge that produced failure. For example, Kim and Miner (2007) found that leaders of banks that experienced visible failures followed by successes were especially likely to reveal information about the conditions that prompted their banks' failures and turnarounds.

Furthermore, even when organization members do not wish to disclose information about a failure, powerful external stakeholders often require such disclosure. The CAIB investigation is an example of a mandated public investigation of failure; similar public investigations frequently follow failures in many industries (Carroll, 1998). Alternately, when an organization's failure leads to its demise, its knowledge becomes accessible to others as its members disperse to join other organizations (Haveman & Cohen, 1994; Kraatz & Moore, 2002). Consequently, we hypothesize that others' prior success experience should have a smaller effect on future organizational performance than does others' prior failure experience.

Hypothesis 2. Observation of others' prior organizational failure experience reduces the likelihood of future organizational failure more than does observation of others' prior organizational success experience.

Depreciation of Knowledge Gained through Success and Failure

In early learning curve studies, all prior experience was assumed to be of equal value for improving current performance. However, more recent work in several different domains has demonstrated that the value of prior experience depreciates over time in such a way that recent experience is more valuable than older experience (Argote, Beckman, & Epple, 1990; Arthur & Huntley, 2005; Darr et al., 1995; Epple, Argote, & Devadas, 1991; Hirsch, 1952; Ingram & Baum, 1997).

Organizational learning theorists have suggested multiple possible explanations for the depreciation of organizational experience. First, knowledge may depreciate as organization members exit, taking a portion of organizational knowledge with them (Argote et al., 1990; Darr et al., 1995). This argument suggests that knowledge should depreciate especially rapidly in organizations with high turnover rates and in those in which knowledge tends to be embedded more in individual memories and less in organizational memory systems (Benkard, 2000). Second, knowledge depreciation may emerge as an unintended consequence when changes to organizational processes or structures disrupt established "transactive memory" systems, destroying tacit, collective knowledge embedded in informal social networks (De Holan & Phillips, 2004; Wegner, 1986). Third, knowledge may be lost as organization members make series of random, small changes to noncodified routines over time (Zucker, 1987). These small, inadvertent changes produce an imperceptibly slow drift in organizational practices that erodes knowledge stores. Both the disruption of transactive memory systems and the drift of organizational routines should lead to greater knowledge depreciation in settings characterized by tacit knowledge than in settings characterized by codified knowledge.

Although organizational learning theory suggests a number of characteristics that may impact the rate at which organizational knowledge depreciates (i.e., codified versus tacit), the difference in the depreciation rates of knowledge derived from various forms of experience has not been previously addressed in this domain. We extend the organizational knowledge depreciation literature to consider differences in the relative deprecation rates of organizational knowledge gained from success experience and failure experience. Although both failure and success may prompt learning, organizational knowledge developed in response to failure is more likely to be codified and embedded in formalized organizational memory systems, and knowledge developed in response to success is more likely to be uncodified. Because failure forces organizational decision makers to recognize gaps in their knowledge, they launch formal knowledge development efforts in response to it (Carroll, 1995; Turner, 1978). These formal knowledge search efforts produce changes in organizational structures and practices such as rules, standard operating procedures, and routines (March, 1981; Nelson & Winter, 1982).

On the other hand, because success reinforces existing bases of organizational knowledge, organizational decision makers are unlikely to alter formal organizational memory systems in response to success. Lessons derived from success, then, are captured primarily in individuals' memories and in informal organizational structures such as transactive memory systems and shared mental models (Weick, 1984). But, as discussed above, noncodified organizational knowledge, whether housed in individual or organizational memory structures, is susceptible to loss through turnover, structural change, and drift; therefore, knowledge gained through success should depreciate more rapidly than that gained through failure. This effect should impact knowledge developed through both direct and vicarious experience.

Hypothesis 3. Knowledge gained through prior direct organizational success experience depreciates more rapidly than does that gained through prior direct organizational failure experience.

Hypothesis 4. Knowledge gained through observation of others' successes depreciates more rapidly than does that gained through observation of others' failures.

Learning from Failure: Boundary Conditions

Although above we specify direct tests of the relative effects of success and failure experience, as well as tests of differences in depreciation between these two forms of experience, we also extend theory in this domain by proposing and testing several boundary conditions on these arguments. Empirical organizational learning research has identified heterogeneity in direct and vicarious organizational learning from experience, suggesting that further examination of the sources of this heterogeneity is warranted (e.g., Baum & Dahlin, 2007; Darr et al., 1995; Ingram & Baum, 1997). We contribute to these efforts by forwarding arguments regarding how one characteristic of experience, the magnitude of failure, and one organizational characteristic, the prior base of failure experience, influence organizations' abilities to learn from the experience associated with these characteristics.

Outcome magnitude. Although organization members tend to engage in problemistic search for new knowledge in response to failure, some learning theorists have argued that not all failures are of equal value in promoting organizational learning. Specifically, theorists have argued that the magnitude of a failure impacts organization members' abilities to learn effectively from it.

The most developed line of thought in this domain is the "small losses" hypothesis, the argument that organizations learn more from small failures than from large failures (Hayward, 2002; Sitkin, 1992; Staw & Ross, 1987; Weick, 1984). According to this argument, following any failure, organization members' and external stakeholders' responses are driven by two, often competing, motives: to learn the causes of the failure so that the likelihood of future failures can be mitigated, and to uncover the causes of the failure so that responsibility for it can be assigned and those responsible can be held accountable (Sagan, 1993; Sitkin, 1992). Following small failures, the drive to determine accountability is attenuated, and learning becomes the primary purpose of organizational search activities. But, following large failures, determining accountability remains an important motive. Under such conditions, organization members may be less likely to share information about the failure, preferring instead to protect themselves from the political fallout surrounding failure investigation (Sagan, 1993). Furthermore, under the threat of being held accountable for failure, they may be less likely to attempt to alter existing organization knowledge, instead displaying a "threat-rigidity response" (Staw & Ross, 1987; Weick, 1984).

We acknowledge the potential of accountability pressures to limit organizational learning following failure, yet we hypothesize the opposite position—that organizations learn more from large failures than small failures. We propose this effect for two reasons. First, because small failures do not have large negative consequences, organization members may redefine small failures as successes (Dillon & Tinsley, 2008; Morris & Moore, 2000). Second, some research has suggested that individuals tend to self-enhance—to dwell on their successes and ignore their failures (Burger, 1981; Ford, 1985). The same tendency has also been observed at the organizational level; members of organizations attend more to information that portrays their organizations in a positive light than to negative information (Elsbach, 1994; Suchman, 1995). Organizational self-enhancement may lead organization members to ignore small failures, but they are unlikely to ignore larger failures because of their magnitude and visibility.

In both cases, the reactions of organization members to small failures could prevent them from engaging in problemistic search for new knowledge and from making significant changes to existing organizational knowledge structures (Levinthal & March, 1981; Wildavsky, 1988).

Hypothesis 5. Prior organizational experience with major failure reduces the likelihood of future organizational failure more than does prior organizational experience with minor failure.

Interactive effects of prior failure experience. Although our primary arguments pertain to differences in learning from successes and failures, respectively, organizational failure experience can also indirectly influence organizations' abilities to learn from their own and others' successes as well as from others' failures. We discuss each of these possibilities in turn below.

First, although we argue above that an organization's experience with failure improves future performance more than its experience with success, it is important to note that organizational learning theory is equivocal regarding the effect of prior success experience on organizational performance. On the one hand, success may promote efficiency in certain cases by signaling that (costly) nonlocal search is unnecessary and that additional changes to organizational knowledge are unlikely to significantly sharpen the organization's internal representation of its domain (Daft & Weick, 1984; Hoffman & Ocasio, 2001). On the other hand, prior success may induce organization members to prematurely adopt suboptimal world-views and to ignore valuable environmental feedback (March, 1991). These latter consequences of prior success are especially harmful to organizational performance under two conditions—when organizational knowledge development in a domain is in an early, formative stage, and when the organizational environment experiences a discontinuous change (Audia et al., 2000; Levinthal & March, 1993).

Members of organizations with limited direct failure experience are especially prone to these consequences from their own and others' successes, as the search for knowledge in these organizations tends to be relatively localized and to reinforce rather than challenge preexisting models of reality (Cyert & March, 1963; March & Simon, 1958; Weick & Roberts, 1993). Members of these organizations, as a result of localized search processes, may lack detailed enough prior knowledge of a domain to draw correct inferences from their own and others' success experience. Instead, members of these organizations may extract knowledge from success experience that is suboptimal in the organization's environment, or may be unable to effectively incorporate knowledge from success experience to guide future activities, since their prior base of knowledge provides limited guidance regarding how to access, evaluate, and utilize knowledge from success experience.

These arguments are analogous to certain arguments regarding the organizational benefits of internal R&D activities. According to the absorptive capacity perspective, an organization must make a certain level of investment in R&D before its members are capable of understanding and employing lessons drawn from externally conducted R&D (Cohen & Levinthal, 1990, 1994). We argue that a similar effect exists in the context of learning from successes. Though organizations may generally be less able to learn from their successes than their failures, an organization with a small base of prior failure experience may actually draw incorrect inferences from its own and others' success experience. That is, such an organization may suffer from experience with success, rather than merely benefit less from success than from failure experience. These arguments apply to an organization's direct success experience as well as to its indirect experience with others' successes.

Hypothesis 6. Prior success experience increases the likelihood of future organizational failure for organizations with relatively little direct failure experience.

Hypothesis 7. Observation of others' prior success experience increases the likelihood of future organizational failure for organizations with relatively little direct failure experience.

An organization's prior failure experience may also influence its ability to learn from others' failures. Although we expect vicarious learning from others' failures to improve organizational performance in general, we anticipate that an organization's ability to learn from the failures of others will be contingent on that organization's own direct failure experience. Extracting meaningful lessons from experience is a challenging exercise at best (Levinthal & March, 1994; March, Sproull, & Tamuz, 1991). The difficulty of vicarious experiential learning is especially pronounced, given the imperfect comparability between the technologies and processes of different organizations. This being the case, members of organizations with underdeveloped internal representations of a domain are likely to draw incorrect lessons from observing the failures of organizations operating in that domain. Since, as we argue above, direct experience with failure is one primary mechanism of organizational knowledge development, at least some direct organizational failure experience may be a prerequisite to benefiting from the observation of others' failures.

Members of organizations with relatively little direct failure experience may be unable to draw valuable lessons from others' failures for at least two reasons. First, members of these organizations are likely to overestimate the similarities between the observed organizations and their own, leading them to learn lessons that are inapplicable to their own organizations. The tendency to assume greater similarity with others than is actually present is a common cognitive bias (known as projection bias), but it is especially prevalent among decision makers with low domain experience (Manski, 1993; Ross, Greene, & House, 1976). Second, members of organizations with relatively little direct failure experience may lack a detailed enough knowledge structure of a domain to draw correct inferences from the others' failures. This is directly parallel to the argument forwarded above with respect to own and others' successes. For both of these reasons, attempts at vicarious learning from others' failures are likely to hinder effective learning in organizations with little direct failure experience.

Hypothesis 8. Observation of others' prior failure experience increases the likelihood of future organizational failure for organizations with relatively little direct failure experience, but it reduces the likelihood of future organizational failure for organizations with significant direct failure experience.

METHODS

We tested our hypotheses in the context of the global orbital launch vehicle industry, with data on a period from its inception in 1957 through March 2004. An orbital launch vehicle is a rocket designed to place a payload (one or more satellites) into orbit around the earth. Attempted space launches are categorized into two major types: suborbital and orbital. Suborbital launches carry a payload out of the earth's atmosphere but do not reach the speed necessary to attain orbit and are immediately pulled back to earth by gravity. Orbital launches exit the atmosphere and reach high enough speeds for the payload to enter orbit. These two types of space launches utilize similar rocket technology, but they represent distinct activities, with an orbital launch being the much more difficult of the two to accomplish. The present study exclusively concerns orbital launches. We refer to the group of organizations that produce and launch orbital launch vehicles as the orbital launch vehicle industry.

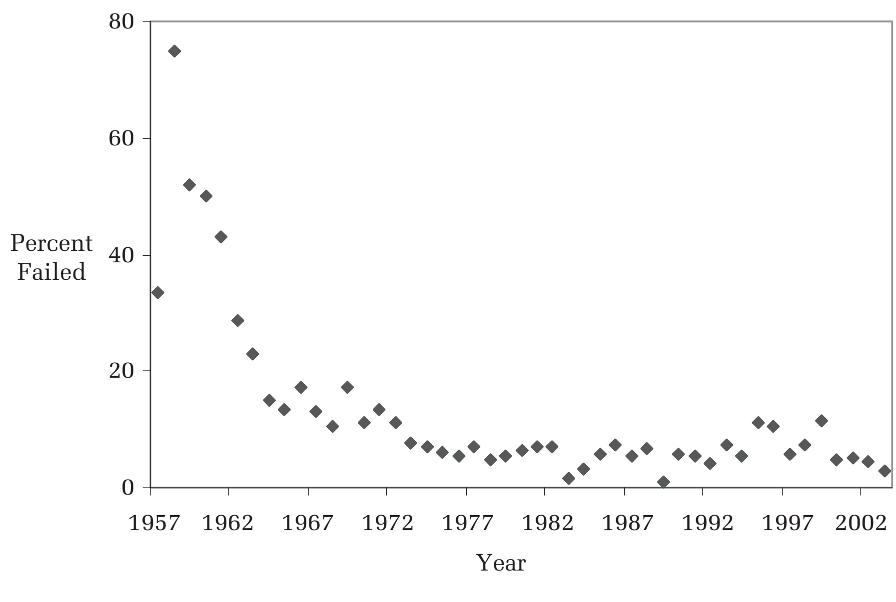
The orbital launch vehicle industry provided a unique arena in which to examine organizational learning from success and failure for several reasons. First, orbital launch vehicle producers have very high incentives to succeed and thus to learn from both success and failure. Although failed launches are extremely costly, successful launches increase a launch organization's reputation and improve access to resources and customers. Second, placing objects into orbit is a relatively new activity. Although scientific work on the idea that rockets could be used for space travel had been occurring since the late 19th century, the earliest orbital launch attempts were made near the end of 1957. Because of this recent origin, accounts of orbital launch attempts are easy to obtain in the historical record, making it possible to compile, with reasonable certainty, a complete list of every orbital launch attempt ever made. The ability to study the entire history of an activity (to avoid "left-censoring") is a significant advantage in studying organizational learning from experience.

Third, failed orbital launch attempts are both salient and relatively frequent. In many of the contexts in which organizational learning curves have been studied, operational failures are either not salient events (and consequently records of failures are not kept), or failures are so infrequent as to prohibit their use in studying organizational learning. Failed orbital launch attempts are highly salient events because they are highly visible (and often very loud) and because they are extremely costly. For example, on January 17, 1997, an explosion during the attempted launch of a U.S. military satellite on a Delta rocket destroyed the satellite and damaged the launch facilities, costing an estimated $150 million (*Florida Today*, 1997). Furthermore, although orbital launch attempts fail much less frequently now than in the 1950s, failures are still frequent enough that reliability is one of the most important considerations for potential launch vehicle customers (Launius & Jenkins, 2002). Figure 1 illustrates the percentage of worldwide orbital launch attempts that failed in each year in the sample. As can be seen, though the failure rate has declined markedly over time, orbital launch failure has by no means been eliminated.

Data and Sample

The sample consists of all orbital launch attempts carried out by any organization worldwide in the period beginning with the launch of Sputnik 1 on October 4, 1957, through March 2004. Many organizations maintain orbital launch databases. To ensure completeness and accuracy, we com-

FIGURE 1
Global Failed Orbital Launch Attempts by Year as a Percentage of Total Attempts



pared several different databases with each other as well as with histories written about various space programs and launch vehicles. The principal launch databases used were these: the National Space Science Data Center's monthly Spacewarn Bulletin (http://nssdc.gsfc.nasa.gov/spacewarn) and its Master Catalogue (http://nssdc.gsfc.nasa.gov/nmc/sc-query.html); NASA's Office of Space Flight's Tables of Space Launches (http://www.hq.nasa.gov/osf/spacestat.html); and Jonathan McDowell's Master Orbital Launch Log (http://www.planet4589.org/space/log/launch.html). A small number of disagreements between orbital launch databases were resolved by referring to published historical accounts of the launches in question. The sample contained 4,663 launch attempts (resulting in 4,220 successes and 443 failures) made by 36 launch vehicle organizations. Launch failure rates varied across organizations, ranging from 7 to 100 percent. The unit of analysis was the orbital launch attempt. To control for unobserved organizational characteristics that might affect launch failure rates, in all estimated models we included organization fixed effects (as explained below). This model specification required that launch attempts made by organizations that never experienced a successful orbital launch be dropped from the sample; consequently, 17 launch attempts (all failures) made by 6 organizations were removed from the sample, leaving 4,646 launch attempts (4,220 successes and 426 failures) made by 30 launch vehicle organizations from 9 countries in the final sample.[1]

Dependent Variable

The dependent variable tracked whether or not a given launch attempt failed. Thus, *failed launch* took the form of a dichotomous dummy variable coded 1 for failed launches and 0 for successful launches. Most launches are either clear failures (they blew up) or clear successes (they did not blow up). However, as in most domains, the line between success and failure in orbital launch attempts blurs a bit when gazed at closely. Some of the launch attempts in the sample resulted in partial failures: they successfully reached earth orbit, but significantly damaged the satellite, failed to obtain separation between the satellite and the launch vehicle, or deposited the satellite into the wrong orbit, limiting the satellite's usefulness. In coding the dependent variable, we considered these launch attempts to be failures because the launch vehicles involved did not properly perform the function for which they were designed. For example, the April 6, 1968, launch of the unmanned Apollo 6 mission is considered a failure here because engine malfunctions during launch caused the spacecraft to enter the wrong orbit, but the April 11, 1970, launch of the famous Apollo 13 mission is considered a success here because the launch vehicle performed properly—even though an explosion in an oxygen tank in the spacecraft forced the lunar landing to be abandoned and nearly killed all three crew members. To verify the validity of this approach, we separated partial launch failures from complete failures in some analyses, as reported below.

Independent Variables

Success and failure experience. The independent variable measuring *success experience* was a count of the number of prior successful launches made by an organization. The independent variable measuring *failure experience* was a count of the number of an organization's prior failed launches. Hypothesis 5 suggests that failure magnitude may affect organizational learning. Although we could not obtain data on the financial costs associated with each failure in the sample, we were able to partition the failures into partial failures and complete failures, as discussed above. Two additional counts, *prior partial failure experience* and *complete failure experience*, constituted two additional independent variables.

During the time covered by the sample, several orbital launch organizations merged with others or were acquired by others. In these cases, success and failure experience were constructed so as to account for all of the prior experience possessed by the merged organizations. For example, when Martin Marietta purchased General Dynamic's Space Systems Division (GDSSD) in 1993, it combined GDSSD's prior experience with the Atlas launch vehicle with its own experience with its Titan vehicle. In this case, success and failure experience for all Martin Marietta launches following the merger included GDSSD's prior experience as well as Martin Marietta's prior experience.

Vicarious experience. To study the possibility of vicarious organizational learning, we measured four additional experience variables: *others' success experience*, *others' failure experience*, *others' partial failure experience*, and *others' complete failure experience*. These variables indexed the number of prior successful launches, total failed launches, partially failed launches, and completely failed launches made by organizations in the sam-

[1] The countries were China, France, Great Britain, India, Japan, Russia, Ukraine, the U.S.A., and the U.S.S.R.

ple other than the organization that was attempting a given orbital launch.

In practice, we constructed the others' experience variables at the country level rather than at the global level, meaning that they indexed the number of prior orbital launch experiences of all other organizations located in the same country as a focal launch vehicle organization. In the context of space technology, the assumption of international knowledge sharing is highly problematic. The vast majority of the sample was composed of launches made by organizations in two countries—the United States and the Soviet Union (U.S.S.R.)—between which no deliberate sharing of knowledge on launch vehicle technology occurred. Furthermore, although there certainly were instances in the sample of international knowledge sharing (U.S. aid to the fledgling Japanese space industry, for example), orbital launch vehicle technology was a closely guarded state secret in all of the countries in which orbital launch organizations were located.

To test our assumption of no significant intercountry knowledge spillover, we conducted preliminary analyses estimating experience at the global level, finding that models including these variables did not exhibit better fit than models including experience at the country level. Furthermore, the coefficient for global experience (net of country-level experience) became nonsignificant once country-level experience was added to models. Collectively, these analyses indicated that estimating knowledge spillover at the country level was warranted in this empirical context.

Control Variables

Several control variables were also included to account for factors other than organizational experience that might impact launch failure probabilities. The first was the *number of stages* that composed a given launch vehicle. These vehicles typically contain more than one stage, each with its own fuel and rocket engine. When a stage has exhausted its fuel supply, it separates from the rest of the vehicle, reducing the weight that must be carried into orbit. The use of many stages can increase the performance of a launch vehicle by keeping its weight to a minimum, but vehicles composed of many stages are also more complex than those composed of few stages. Since this complexity is thought to increase the probability of launch failure, the number of stages in each launch vehicle should be controlled (*launch vehicle number of stages)*. Similarly, launch vehicles with the capacity to carry heavy payloads into orbit are larger and more complex than those designed to carry smaller payloads, so the former may have higher probabilities of failure. For this reason, the number of pounds that a launch vehicle was capable of lifting to low earth orbit (orbits between 200 to 500 miles above the earth) was included as a control variable, expressed in hundreds of pounds (*launch vehicle low earth orbit capacity*). *Launch vehicle height* (in meters) was also included to control for the possibility that the added complexity of building very tall launch vehicles increased their likelihood of failure.

Calendar time, specified as the year of a launch, was included to control for changes in available technology over time that might impact launch performance. Similarly, a dummy variable, *post 1991*, was included to indicate if a launch occurred after 1991. The fall of the U.S.S.R. in December 1991 drastically altered the launch vehicle market. The advancement of orbital launch technology had for decades developed largely as a competition between two world political powers. The dissolution of one of those powers marked a dramatic shift in the industry.

Another important control variable involved the effect of mergers and acquisitions. As noted previously, several mergers and acquisitions of orbital launch organizations occurred during the sample period. We constructed all experience measures assuming that knowledge gained through prior experience passed completely to the merged company (or to the acquirer). But this assumption may not completely hold if tacit knowledge transfer is incomplete in mergers and acquisitions. As a control for this possibility, a continuous variable counting the number of *mergers and acquisitions* in a launch organization's history prior to the observed launch was included in the analysis.

Analysis

We used logistic regression analysis to model the likelihood that a given launch attempt resulted in failure and included organization-specific fixed effects to control for unobserved heterogeneity among orbital launch organizations (Allison, 1999). The fixed-effects regression model takes the form:

$$\log\left(\frac{\mathrm{P}_j}{1-\mathrm{P}_j}\right) = a + b_i + \boldsymbol{c}x_j, \tag{1}$$

where P_j is the probability that launch j will fail, a is a constant term, b_i is the organization fixed effect and represents all characteristics of organization i that are stable over time, and $\boldsymbol{c}$ is a vector of coefficients for the independent and control variables (x) for launch j. The inclusion of organization fixed effects was critical because many characteristics of orbital launch organizations were unobservable during the sample period. If not controlled, interorganizational heterogeneity in these characteristics could have biased the regression results.

Since one of the purposes of the study was to examine the relative rates of depreciation of knowledge gained through prior success and failure, it was also important to develop a method for modeling knowledge depreciation. Two such methods have been used in previous research. The first method utilizes a series of arbitrarily selected discount factors by which prior experiences are divided before being summed into a cumulative prior experience variable (see Baum & Ingram, 1998; Haunschild & Sullivan, 2003; Ingram & Baum, 1997). Typical values assigned to the discount factor include: 1 (assuming that knowledge is nondepreciating), the age of experience (assuming that knowledge depreciates linearly), the age of experience squared, and the square root of age of experience. Authors employing this method estimate their models using all four discounting factors and select the one that yields the best model fit for use in their subsequent analysis.

The second method introduces into the model a depreciation parameter, lambda (λ), that represents the fraction of experientially derived knowledge possessed by an organization in one time period that remains in the next time period (see Argote et al., 1990; Arthur & Huntley, 2005; Darr et al., 1995). The depreciation parameter can take any value between 0 and 1, with a value of 0 indicating complete organizational amnesia (knowledge from one time period is completely forgotten in the next) and a value of 1 indicating perfect organizational memory (knowledge does not depreciate at all with time).

The two methods are similar; both permit considering various depreciation rates, selecting the one that produces the best model fit, and then estimating the remaining coefficients using the selected depreciation rate. However, for the purposes of this study, the second method had the added benefit of producing an estimate of lambda, which indicates the rate of knowledge depreciation. This method was used here. When lambda took a value of 1, depreciated (success or failure) experience was equivalent to that described above. However, when lambda took any other value, the depreciated experience of organization i prior to launch j was determined by

$$Experience_{ij} = \sum_{k=1}^{k=j-1} Launch_{ik} \times \lambda^{year_j - year_k}, \tag{2}$$

where λ is the depreciation parameter, $year_j$ is the year in which launch j occurred, and $year_k$ is the year of launch k. The value of experience for a given launch is the sum of prior launches by the launching organization, each multiplied by the depreciation factor raised to the power of the number of years separating each prior launch from the current launch.

We used a grid search procedure for maximum likelihood estimation to determine the value of lambda, which maximizes model fit (Judge, Griffiths, Hill, Lutkepohl, & Lee, 1985). In the grid search, preliminary models were estimated using all possible values of lambda between 0 and 1 in increments of 0.01, and the value that maximized models' log-likelihood was selected. Importantly, the grid search procedure was performed separately for models containing each of the different types of experience examined (success, failure, partial failure, complete failure, others' success, others' failure, others' partial failure, others' complete failure), allowing a different value of lambda to be determined for each. For hypothesis tests involving knowledge depreciation, we determined a 99% confidence interval for each lambda using the log-likelihood functions of the models estimated in the grid search (see Argote et al., 1990; Arthur & Huntley, 2005).

RESULTS

Table 1 presents descriptive statistics and correlations for the study variables. Each of the experience-related variables reported in the table was depreciated using its best-fitting depreciation parameter, lambda, as described above. These depreciation parameters are reported in parentheses after the variable names. As can be seen in Table 1, some very high correlations exist among certain variables. For example, the correlations between failure experience and complete failure experience (r = .98) as well as that between others' failure experience and others' complete failure experience (r = .99) are extremely high; however, no models simultaneously include both of a pair of highly correlated variables.

In addition, the correlation between success experience and failure experience is .81. One reason for the fairly high correlation could be that success and failure experience both increase as a launch organization gains overall experience. To determine whether success and failure experience contributed information to the models independent of total experience, we conducted preliminary tests to estimate the impact of an organization's own total launch experience, as well as others' total launch experience, on launch failure likelihood. Although total launch experience had a significant effect on launch failure likelihood, models separating this

TABLE 1
Descriptive Statistics and Correlations[a]

Variable	Mean	s.d.	Minimum	Maximum	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Failed launch	0.09	0.29	0	1														
2. Success experience (λ = .34)	34.77	29.65	0.00	91.42	−.15													
3. Failure experience (λ = .89)	13.81	8.89	0.00	29.75	−.12	.81												
4. Partial failure experience (λ = .90)	3.52	2.64	0	9	−.13	.78	.76											
5. Complete failure experience (λ = .89)	11.02	7.28	0	24	−.11	.78	.98	.65										
6. Others' success experience (λ = .00)	43.48	28.47	0	84	−.13	.75	.69	.56	.69									
7. Others' failure experience (λ = .85)	23.17	13.62	0	47	−.05	.41	.60	.38	.61	.73								
8. Others' partial failure experience (λ = .84)	5.60	3.15	0	15	−.09	.31	.41	.47	.37	.60	.77							
9. Others' complete failure experience (λ = .87)	20.81	12.66	0	43	−.06	.44	.61	.37	.63	.76	.99	.71						
10. Launch vehicle number of stages	3.23	1.07	1	6	.03	−.07	−.16	.08	−.22	.01	−.06	.03	−.07					
11. Low earth orbit capacity	5,442.08	8,126.42	11	118,000	.00	−.02	−.15	−.03	−.17	−.02	−.07	.03	−.07	.09				
12. Launch vehicle height	41.16	11.10	12	111	−.09	.25	.03	.25	−.03	.14	−.15	−.01	−.14	.37	.57			
13. Calendar time	1,980.32	11.71	1,957	2,004	−.17	−.09	−.42	−.12	−.44	−.22	−.58	−.37	−.56	.20	.18	.39		
14. Post 1991	0.23	0.42	0	1	−.06	−.33	−.47	−.28	−.48	−.43	−.51	−.42	−.50	.15	.13	.21	.75	
15. Mergers and acquisitions	0.19	0.48	0	2	−.03	−.26	−.29	−.21	−.29	−.31	−.26	−.20	−.26	.03	.07	.03	.35	.41

[a] n = 4,646. Values in parentheses for lambda are best-fitting depreciation parameters.

TABLE 2
Results of Fixed-Effects Logistic Regression Models of Launch Failure Likelihood for Global Orbital Launches, 1957–2003[a]

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Success experience ($\lambda = .34$)		−0.02*** (0.00)		0.00 (0.01)	
Failure experience ($\lambda = .89$)			−0.08*** (0.01)	−0.08*** (0.01)	
Partial failure experience ($\lambda = .90$)					
Complete failure experience ($\lambda = .89$)					
Others' success experience ($\lambda = .00$)					−0.01*** (0.00)
Others' failure experience ($\lambda = .85$)					
Others' partial failure experience ($\lambda = .84$)					
Others' complete failure experience ($\lambda = .87$)					
Number of launch vehicle stages	0.31*** (0.09)	0.29** (0.09)	0.34*** (0.09)	0.34*** (0.09)	0.30** (0.09)
Low earth orbit capacity	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Launch vehicle height	−0.02 (0.01)	−0.01 (0.01)	−0.01 (0.01)	−0.01 (0.01)	−0.01 (0.01)
Calendar time	−0.11*** (0.01)	−0.08*** (0.01)	−0.10*** (0.01)	−0.10*** (0.01)	−0.09*** (0.01)
Post 1991	1.14*** (0.27)	0.48 (0.28)	0.54* (0.26)	0.55* (0.28)	0.60* (0.27)
Mergers and acquisitions	2.62* (1.22)	2.59* (1.21)	2.77* (1.21)	2.77* (1.22)	2.50* (1.21)
Log-likelihood	−1,230.94	−1,215.87	−1,198.82	−1,198.82	−1,216.64
Likelihood ratio		30.15***	64.24***	34.10***	28.61***
df (vs. model no.)		1 (m1)	1 (m1)	1 (m2)	1 (m1)
Likelihood ratio				0.00	
df (vs. model no.)				1 (m3)	

[a] $n = 4{,}646$ (4,220 successes and 426 failures). Standard errors are in parentheses. Fixed-effects coefficients are included but not displayed.
* $p < .05$
** $p < .01$
*** $p < .001$

construct into success experience and failure experience yielded significantly better model fit. This finding suggests that success experience and failure experience contributed independent information to estimation models despite their fairly high correlation. As a result, models including total experience were omitted from the final results. To further alleviate multicollinearity concerns, here we report nested models across the analysis. Since model fit is not affected by multicollinearity, we compared model fit across sets of nested models and verified results with likelihood-ratio tests.

Table 2 reports maximum-likelihood estimates for the fixed-effects logistic regression analysis of orbital launch failures. Model 1 contains only control variables and provides a baseline against which models containing experience variables are compared. In model 1, the coefficients for the number of stages and the low earth orbit capacity of launch vehicles are both highly significant and positive, indicating that the complexity associated with large launch vehicles and launch vehicles employing many stages increases the probability that launches using such vehicles will end in failure. Launch vehicle height does not seem to play a significant role in launch success or failure.

The coefficient for calendar time is negative and significant in model 1, suggesting that advances in rocket science and launch vehicle technology were being made during the time covered by the sample. Interestingly, however, launches occurring after 1991 were more likely to fail than those occurring before the end of 1991 (with the time trend controlled for). This result may be a result of diminished government funding for launch vehicles after the end of the Cold War. Finally, the coefficient for the mergers and acquisitions variable is also significant and positive, suggesting that organizational knowledge may not completely transfer to a merged company or an acquirer.

TABLE 2
Continued

Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
		0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
		−0.07*** (0.02)		−0.08*** (0.02)	
			−0.0 (0.05)		−0.02 (0.06)
			−0.08*** (0.02)		−0.08*** (0.02)
	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
−0.04*** (0.01)	−0.06*** (0.01)	−0.03 (0.01)	−0.03 (0.01)		
				−0.03 (0.03)	−0.03 (0.03)
				−0.03 (0.02)	−0.03 (0.02)
0.29** (0.09)	0.29** (0.09)	0.32*** (0.09)	0.32*** (0.09)	0.32*** (0.09)	0.32*** (0.09)
0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)
−0.01 (0.01)	−0.01 (0.01)	−0.01 (0.01)	−0.01 (0.01)	−0.01 (0.01)	−0.01 (0.01)
−0.11*** (0.01)	−0.12*** (0.01)	−0.11*** (0.01)	−0.11*** (0.01)	−0.11*** (0.01)	−0.11*** (0.01)
0.77** (0.26)	0.97** (0.28)	0.71* (0.29)	0.72* (0.30)	0.70* (0.29)	0.70* (0.29)
2.26 (1.20)	2.18 (1.19)	2.51* (1.21)	2.52* (1.21)	2.46* (1.21)	2.47* (1.21)
−1,207.52	−1,205.91	−1,195.81	−1,195.89	−1,195.42	−1,195.51
46.85***	21.45***	20.21***	−0.17	0.76	0.59
1 (m1)	1 (m5)	2 (m7)	1 (m8)	2 (m8)	2 (m8)
	3.22	6.02*			
	1 (m6)	2 (m4)			

Learning from Firsthand Experience

Models 2 through 4 estimate the effect of a focal organization's experience on launch failure likelihood. Model 2 includes the organization's success experience. The success experience coefficient is negative and significant, indicating that failures may become less likely as success experience increases. The knowledge depreciation parameter (lambda) was .34 for success experience, suggesting that of the knowledge an organization gains from successful launches occurring during a given year, only 34 percent will remain one year later. This rate of knowledge loss, although it may seem rapid, indicates a much lower rate of organizational forgetting than is typically described in the literature, in which reports of monthly depreciation parameters of .75–.85 are common (see Argote, 1999). Extrapolated to an annual rate, these lambdas indicate that less than 10 percent of organizational knowledge is retained after one year.

Model 3 includes failure experience (and removes success experience). The coefficient for failure experience is negative and highly significant. The failure experience coefficient also remains significant in model 4, where it is included along with success experience. Furthermore, the coefficient for success experience loses significance in model 4, indicating that failure experience better explains variation in launch failure likelihood than success experience. To confirm this finding, we conducted a Wald test; its result ($p < .001$) indicated that the failure experience coefficient in model 4 is significantly more negative than the success experience coefficient. This finding is consistent with the argument that organizations learn more from prior failures than they do from prior successes. It is also supported by a set of likelihood ratio tests that indicate that model 4 fits the data significantly better than model 2, which includes only success experience; but model 4 does not fit the data better than model 3, which includes only failure experience. Collectively, these results support Hypothesis 1, suggesting that prior failure experience reduces failure likelihood more than does prior success experience.

Furthermore, success experience depreciates more rapidly than failure experience ($\lambda = .34$ vs. 89). The 99% confidence intervals for the failure experience and the success experience lambdas do not overlap, indicating that knowledge gained from success experience depreciates significantly more rapidly (significant at the .01 level) than does knowledge gained from failure experience. This finding strongly supports Hypothesis 3.

Learning from Vicarious Experience

Models 5–7 repeat the tests reported above for the case of vicarious organizational experience. A similar pattern of results appears. Although others' success experience has a negative and significant impact on failure likelihood in model 5, this effect loses significance when others' failure experience is included in model 7. The coefficient for others' failure experience is negative and highly significant in both models 6 and 7. A Wald test ($p < .001$) suggested that the others' failure experience coefficient in model 7 is significantly more negative than the coefficient for others' success experience, and likelihood-ratio tests indicated that model 7 fits significantly better than model 5, but not better than model 6. These results support Hypothesis 2, indicating that others' failure experience reduces the failure likelihood at a focal organization more than does others' success experience. Furthermore, others' success experience depreciates significantly ($p < .01$) more rapidly than does others' failure experience (the 99% confidence intervals for the others' failure experience lambda and the others' success experience lambda do not overlap). This finding supports Hypothesis 4.

The results from models 2–7 are also consistent with findings in model 8, which simultaneously includes own and others' success and failure experience variables. The coefficient for others' failure experience is no longer significant, but the coefficient for own failure experience retains significance. A Wald test confirmed that the own failure experience coefficient is significantly more negative than the own success experience coefficient, a pattern that is consistent with the pattern of results in model 4. However, the others' failure experience coefficient is no longer significantly more negative than the others' success experience coefficient. Thus, Hypothesis 2 is partially supported, with support limited to that obtained in model 7.

Outcome Magnitude

To address the effects of the magnitude of failure outcomes, model 9 in Table 2 separates a focal firm's failure experience into experience with partial failures and experience with complete failures. Experience with complete failures significantly reduces launch failure likelihood, and experience with partial failures has no effect. This pattern of results provides support for Hypothesis 5. It also suggests that organizations in the sample generally did not learn more effectively from small failures than from large failures, a notion that stands in contrast to arguments in the literature on learning from small losses. In fact, the evidence seems to support the opposite conclusion—that the organizations learned more effectively from experience with large failures.

Model 10 splits others' failure experience into partial and complete failures, revealing no significant effect for either of these variables on the future failure rates of a focal organization. Neither of these variables' coefficients is significantly more negative than others' success experience. Thus, Hypothesis 5 is only supported with respect to a focal organization's own experience, and not with respect to the magnitude of other organizations' failures. Model 11, which simultaneously splits own and others' failures into partial and complete failures, provides a pattern of results similar to those in models 9 and 10.

Interactive Effects of Prior Experience

To test Hypotheses 6 and 7, regarding the effects of prior failure experience on learning from an organization's own and other organizations' success experience, and to test Hypothesis 8, regarding the effect of prior failure experience on learning from others' failures, we estimated models for two subsamples, one containing launches conducted by organizations with fewer than two prior failures, and the other containing launches conducted by organizations with two or more prior failures. This cutoff was chosen to facilitate comparison of effects for organizations with limited prior failure experience to those with more substantial failure experience. Table 3 presents the results of these analyses.

Model 1 includes launch attempts by organizations with fewer than two prior failures, and model 2 focuses on launches by organizations with two or more prior failures. Both models estimate effects of the launching organizations' own success and failure experience, as well as the effects of other organizations' success and failure experience. The coefficient for success experience in model 1 is significant and positive, indicating that success experience increases the likelihood of organizational failure for organizations with limited prior failure experience. This provides support for Hypothesis 6. The coefficient for others' success experience, however, is nonsignificant, and Hypothesis 7 is not

TABLE 3
Results of Fixed-Effects Logistic Regression Models of Launch Failure Likelihood: Comparison between Less than Two and Two or More Prior Failures[a]

Variables	Model 1: Prior Failures < 2		Model 2: Prior Failures ≥ 2	
Success experience (λ = .34)	0.55*	(0.24)	0.00	(0.01)
Failure experience (λ = .89)	−3.71**	(1.17)	−0.06***	(0.02)
Others' success experience (λ = .00)	−0.04	(0.06)	0.01	(0.01)
Others' failure experience (λ = .85)	0.37*	(0.17)	−0.03*	(0.02)
Number of launch vehicle stages	1.55*	(0.61)	0.27**	(0.09)
Low earth orbit capacity	0.01	(0.01)	0.01***	(0.00)
Launch vehicle height	−0.17	(0.10)	−0.01	(0.02)
Calendar time	0.28	(0.15)	−0.11***	(0.01)
Post 1991	1.95*	(2.24)	0.73*	(0.31)
Mergers and acquisitions	4.32	(3.08)	12.77	(705.89)
Log-likelihood	−48.66		−1,053.72	
n	238		4,336	
Successes	196		4,024	
Failures	73		370	

[a] Standard errors are in parentheses. Fixed-effects coefficients are included but not displayed.
* $p < .05$
** $p < .01$
*** $p < .001$

supported. The coefficient for others' failure experience is positive and significant in model 1 but is negative and significant for organizations with two or more prior failures in model 2. This difference in sign suggests that others' failures incrementally increase failure likelihood at organizations with limited prior failure experience but that this effect reverses for organizations with more prior failures. This pattern of results supports Hypothesis 8.

Interestingly, findings across the models in Table 3 also suggest that direct failures have a marginally diminishing impact on learning outcomes, since the coefficient of the effect size for failure experience is less negative for organizations with two or more prior failures than for those with fewer than two.

Robustness Checks

In addition to the main analyses reported above, we conducted several supplemental analyses to assess whether our patterns of results were robust to alternate specifications and samples. First, we separated our primary dependent variable, tracking launch failure, into partial and complete failure to determine whether our findings were consistent, given that organizations may experience various forms of failure in this empirical domain. As discussed above, our primary analyses dichotomized launch attempts into failures and successes. Given that failure in this and other empirical settings may vary in severity, it was necessary to assess whether our arguments regarding the relative effects of learning from failures relative to successes held with respect to different failure outcomes. To that end, we estimated the effects of experience on failure outcomes using multinomial logistic regression models with failure outcomes separated into partial and complete failures. Table 4 reports results for these models.

In keeping with prior results, a focal launch organization's own failure experience only has a significant negative impact on complete failures and does not significantly reduce the likelihood of partial failures. This effect is significantly more negative than the effect of success experience, and it is consistent with our primary arguments regarding the relative effectiveness of learning from failures over successes. Similarly, when failure experience is separated into experience with partial and complete failures, and the significant, negative coefficient for own complete failure experience suggests that experience with complete rather than partial failures drives the benefit of failure experience. Interestingly, in all these models, others' failure experience does not significantly affect the likelihood of complete failures, and no forms of experience significantly affect the likelihood of partial failures. This absence of effect may occur because partial failures were relatively rare in this empirical setting; out of 4,646 total launch attempts, only 92 partial failures occurred (versus 334 complete fail-

TABLE 4
Results of Multinomial Logistic Regression Models of Likelihood for Partial or Complete Failure Outcome, 1957–2003[a]

Variables	Model 1 Partial Failure	Model 1 Complete Failure	Model 2 Partial Failure	Model 2 Complete Failure	Model 3 Partial Failure	Model 3 Complete Failure
Success experience (λ = .34)			0.01 (0.01)	0.00 (0.01)	0.01 (0.01)	0.00 (0.01)
Failure experience (λ = .89)			−0.04 (0.03)	−0.07*** (0.02)		
Partial failure experience (λ = .90)					−0.22 (0.12)	0.02 (0.06)
Complete failure experience (λ = .89)					0.02 (0.05)	−0.10*** (0.03)
Others' success experience (λ = .00)			0.01 (0.01)	0.01 (0.01)	0.00 (0.01)	0.01 (0.01)
Others' failure experience (λ = .85)			−0.05 (0.03)	−0.02 (0.02)		
Others' partial failure experience (λ = .84)					0.02 (0.08)	−0.05 (0.04)
Others' complete failure experience (λ = .87)					−0.05 (0.03)	−0.02 (0.02)
Number of launch vehicle stages	1.13*** (0.18)	0.02 (0.10)	1.14*** (0.18)	0.03 (0.10)	1.04*** (0.18)	0.04 (0.10)
Low earth orbit capacity	0.00* (0.00)	0.00*** (0.00)	0.00* (0.00)	0.00** (0.00)	0.00* (0.00)	0.00** (0.00)
Launch vehicle height	−0.12*** (0.03)	0.02 (0.02)	−0.11*** (0.03)	0.03 (0.02)	−0.11*** (0.03)	0.03 (0.02)
Calendar time	−0.07*** (0.02)	−0.03*** (0.01)	−0.09*** (0.02)	−0.12*** (0.01)	−0.07** (0.02)	−0.12*** (0.01)
Post 1991	1.00* (0.48)	1.18*** (0.31)	0.87 (0.53)	0.65 (0.34)	0.76 (0.53)	0.69* (0.34)
Mergers and acquisitions	3.07 (1.57)	20.47*** (0.59)	2.74 (1.58)	20.49*** (0.60)	2.69 (1.58)	21.29*** (0.60)
Log-likelihood	−1,407.76		−1,372.74		−1,370.03	
Likelihood ratio			70.05***		75.46***	
df (vs. model no.)			8 (m1)		12 (m1)	

[a] n = 4,646 (4,220 successes, 92 partial failures, and 334 complete failures).
Standard errors are in parentheses. Fixed-effects coefficients are included but not displayed.
* $p < .05$
** $p < .01$
*** $p < .001$

ures). Collectively, these analyses are consistent with our arguments regarding the relative effectiveness of an organization's learning through its own failure relative to learning from its successes, although we only found a significant impact on complete failure outcomes.

Second, given the low frequency of failures relative to successes in our overall sample, it is possible that their rarity could promote learning from failures in our setting outside of our hypothesized processes. To examine this possibility, we replicated our analyses in subsamples with more comparable rates of failure and success. In the full sample, only 426 failures occurred out of 4,646 launch attempts, making success more than 9 times more common than failure. Failures may receive more attention from organizational decision makers merely because they occur infrequently (and consequently are seen as particularly salient). If this is the case, the relative frequency of prior successes and failures may constitute an important boundary condition on organizational learning from failure. Therefore, it was necessary to address whether differential organizational reactions to success and failure derive from managerial reaction to having met or failed to meet organizational aspirations (Lant, 1992; March, 1981), and not from the level of attention each event garners. Consequently, we tested whether prior failure experience reduced the likelihood of future organizational failure more than did prior success experience, even when prior organizational successes and failures were equally common.

To conduct this test, we estimated models on a subsample that included launch attempts by organizations that had made fewer than five prior launch attempts. Early in their launch histories, organizations experienced approximately equivalent rates of success and failure. For instance, the failure rate for all organizations in the subsample was 42 percent. Thus, organizations with four or fewer prior launch attempts comprise a subsample of organizations with approximately similar rates of success and failure within their own launch histories. Table 5 reports the results of these analyses. As can be

TABLE 5
Results of Fixed-Effects Logistic Regression Models of Launch Failure Likelihood for Global Orbital Launches, Organizations with Fewer than Five Prior Launch Attempts[a]

Variables	Model 1		Model 2		Model 3		Model 4	
Success experience (λ = .34)			0.89	(0.82)			1.35	(2.18)
Failure experience (λ = .89)			−5.12**	(1.49)			−15.84**	(5.39)
Others' success experience (λ = .00)					−0.03	(0.07)	0.23	(0.19)
Others' failure experience (λ = .85)					−0.07	(0.08)	1.16	(0.76)
Number of launch vehicle stages	1.31*	(0.56)	1.56*	(0.64)	1.34*	(0.57)	2.45**	(0.86)
Low earth orbit capacity	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Launch vehicle height	0.04	(0.10)	0.13	(0.12)	0.07	(0.10)	0.04	(0.14)
Calendar time	−0.18	(0.17)	0.69*	(0.35)	−0.17	(0.17)	2.53*	(1.04)
Post 1991	19.83**	(6.41)	17.51	(14.30)	19.82**	(6.94)	15.37	(51.50)
Log-likelihood	−70.35		−53.18		−69.55		−42.45	
Likelihood ratio			34.33***		1.59		55.80***	
df (vs. model no.)			2 (m1)		2 (m1)		4 (m1)	

[a] $n = 151$ (88 successes and 63 failures). Standard errors are in parentheses. Fixed-effects coefficients are included but not displayed.
* $p < .05$
** $p < .01$
*** $p < .001$

seen, results for models estimated on the restricted sample are consistent with those reported above. Collectively, the results of this analysis demonstrate that the relative efficacy of organizational learning through experience with failure and success is not driven by the relative frequencies of success and failure events.

To further examine whether our findings were susceptible to the relative rarity of failure events, we also estimated several models on a partial data set including only launches occurring prior to 1962. We took this approach because the average failure rate of manufacturers was extremely high during the industry's infancy and dropped dramatically during 1962 (see Figure 1). The pre 1962 subsample contains an approximately equivalent number of successes and failures for the overall industry (69 successes and 68 failures). Table 6 displays the models estimating launch failure likelihood for this partial data set. Again, the results of models estimated on the pre 1962 subsample suggest that the difference between organizational learning from success experience and failure experience is not driven by the relative frequency of the two events. Rather, this difference appears to occur through organization-

TABLE 6
Results of Fixed-Effects Logistic Regression Models of Launch Failure Likelihood for Global Orbital Launches Using Partial Data Set, 1957–61[a]

Variables	Model 1		Model 2		Model 3		Model 4	
Success experience (λ = .34)			0.28*	(0.13)			0.28*	(0.14)
Failure experience (λ = .89)			−0.77**	(0.28)			−0.76**	(0.28)
Others' success experience (λ = .00)					0.05	(0.18)	0.01	(0.22)
Others' failure experience (λ = .85)					0.00	(0.09)	0.01	(0.11)
Number of launch vehicle stages	1.24	(0.75)	1.24	(0.84)	1.19	(0.75)	1.24	(0.84)
Low earth orbit capacity	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Launch vehicle height	−0.15	(0.16)	−0.18	(0.18)	−0.13	(0.16)	−0.17	(0.19)
Calendar time	−0.45	(0.26)	1.44	(0.75)	−0.67	(0.51)	1.31	(0.92)
Mergers and acquisitions	1.17	(1.17)	0.02	(1.25)	1.04	(1.30)	−0.08	(1.42)
Log-likelihood	−84.55		−80.15		−84.41		−80.13	
Likelihood ratio			8.80*		0.28		8.85	
df (vs. model no.)			2 (m1)		2 (m1)		4 (m1)	

[a] $n = 137$ (69 successes and 68 failures). Standard errors are in parentheses. Fixed-effects coefficients are included but not displayed.
* $p < .05$
** $p < .01$

al learning processes arising from exposure to success and failure.

DISCUSSION AND CONCLUSION

These findings do not imply that organizations that fail in period t are more likely to succeed in period $t + 1$ than are organizations that succeed in period t. But they do imply that organizations that fail in period t improve their own likelihood of succeeding in period $t + 1$ (relative to their likelihood of success in period t) more than do organizations that succeed in period t. Our definition of learning is inherently self-focused—change in organizational performance as a result of prior experience. This approach to learning is mirrored by the analytical approach of estimating models with fixed organization effects, as fixed-effects models inherently examine within-organization, rather than between-organization, variation. Consequently, the results presented here suggest that experience with failure allows organizations to improve their performance relative to their own previous baseline, but that experience with success does not generate similar levels of improvement.

Indeed, this study not only yielded strong evidence that organizations learn by observing their own and others' failures, but also failed to uncover evidence of significant learning from observation of their own or others' successes. In the full models, coefficients estimating the effect of success experience on future performance are indistinguishable from zero. We do not interpret these results as evidence that organizations cannot learn from success to improve performance. But the fact that launch vehicle organizations (which face significant incentives to learn from success as well as failure) did not experience demonstrable learning from success suggests that organizational learning from success is far from an automatic process.

Theoretical Contributions

This work contributes to organizational learning theory in several ways. First, it empirically confirms theoretical arguments that organizations learn to improve their performance more significantly through experience with failure than through experience with success, as discussed above. Although several recent studies have demonstrated organizational learning from both direct and vicarious experience with failure, previous evidence that failure promotes improvement more than does success had been entirely anecdotal. This study constitutes the first direct comparison of the magnitude of the effects of learning from failure and learning from success. It confirms the suggestion that organizational experience in the aggregate may be of little value (from a learning perspective) other than to provide opportunities for failure.

Second, this work answers significant questions concerning the boundary conditions of learning from failure and success. Our argument is in contrast with the small-losses hypothesis (Hayward, 2002; Sagan, 1993; Sitkin, 1992), in that we argue that organizations learn more effectively from large failures than from small failures. Study results support this view. We do not interpret this finding as evidence that learning from small failures is impossible. But it does suggest that learning from small failures is problematic. Indeed, the analysis uncovered no evidence that organizations learn more effectively from small failures than they do from successes (neither effect being significantly different from zero).

Two major obstacles stand in the way of attempts to learn from any failure: the difficulty extracting of meaningful knowledge from the experience, and political posturing to assign responsibility for the failure. The first obstacle is especially problematic for attempts to learn from small failures, and the second especially problematic for attempts to learn from large failures. Our results indicate that the difficulty of deriving meaningful knowledge from small failures may be a more significant concern than scapegoating in the wake of major failures. Indeed, our results are consistent with the notion that the effort to determine accountability following large failures drives organizational learning, as decision makers with poor understandings of an organization's domain may be replaced by decision makers with more accurate knowledge. As with learning from success, learning from small failures appears to be a challenge too great for common organizational knowledge management approaches to overcome.

We also argue that the process of vicarious learning from failure, as well as learning from an organization's own and others' successes, depends critically on direct learning from failure. Our findings suggest that organizations require a sufficient base of failure experience to extract and effectively apply knowledge from others' failures and that those with relatively little direct failure experience may misapply knowledge from their own successes and others' failures. Research on organizational learning increasingly examines how various forms of experience may interactively affect organizational learning processes (e.g., Baum & Dahlin, 2007). Our findings advance the theoretical literature in this area by forwarding such joint mechanisms and by explicating why some forms of experience may actually be detrimental to learning processes for organizations without prior bases of requisite knowledge.

Finally, this work presents the first attempt to measure and compare the relative depreciation rates of knowledge gleaned from success and failure. It illustrates that not only do failures contribute more to learning than do successes, but that their lessons are also forgotten much more slowly. The estimated depreciation parameters for failure experience were significantly larger than those estimated for success when both direct and vicarious experience were considered, suggesting that knowledge developed in response to failure is embedded in more stable, codified memory systems than is knowledge developed through success. Not only is this a novel finding in the context of failure and success, but it is the first theoretical suggestion and empirical demonstration of which we are aware that organizational knowledge developed through different mechanisms depreciates at different rates. This finding has serious implications for the study of organizational memory and organizational forgetting (de Holan & Phillips, 2004; Zellmer-Bruhn, 2003). Knowledge depreciation represents a central aspect of organizations' abilities to learn from their own and others' experience, yet little research has examined the mechanisms through which knowledge depreciation occurs. Our study's findings suggest a taxonomy of knowledge forms that vary in their permanence and indicate the need for additional research into organizational forgetting in other environments and other categories of experience.

Implications for Practice

One of the biggest current challenges to the organizational learning curve paradigm (and its practical application) is to determine the causes of observed interorganizational variations in learning rates (Huber, 1991; Pisano, Bohmer, & Edmondson, 2001). The findings of this study suggest that one important factor in explaining this variation could be how organizations deal with failure. Failure is often difficult for organization members to cope with. Because failures—and those that appear to be involved in them—are often stigmatized, organization members frequently refuse to acknowledge failure, refrain from communicating about it, or redefine it as success (March et al., 1991). Indeed, in Vaughan's (1996, 2005) analyses of the *Challenger* and *Columbia* disasters, she noted that the most significant organizational antecedent to both tragedies was the institutionalized practice of ignoring failures.

Nonetheless, given failure's central role in organizational learning shown here, organizations that stigmatize failure may be depriving themselves of major opportunities for improvement. Consequently, the most significant implication of this study for practice is that organization leaders should neither ignore failures nor stigmatize those involved with them; rather, leaders should treat failures as invaluable learning opportunities, encouraging the open sharing of information about them. Indeed, this suggestion dovetails with existing evidence that members of organizations that treat failure nonpunitively report more errors, but experience fewer serious failures, than members of organizations that seek to assign blame for failures (Edmondson, 1999; Weick, Sutcliffe, & Obstfeld, 1999).

A second important implication of this research is its illustration of the difficulty organizations face in learning from small failures. Although we find it reassuring that organizations learn from large failures, lessons from large failures are "lessons learned in blood" (Madsen, Desai, Roberts, & Wong, 2006). Organizations obviously cannot explicitly seek to gain experience with failures when the resulting costs of failure to themselves, their stakeholders, and society are prohibitively high. A more desirable alternative would be for organizations to learn enough through success and small failure to avoid large failures entirely. Indeed, drawing knowledge from the collection of information about near-misses (which may be thought of as very small failures) is currently considered a "best practice" for promoting safety in several high-hazard industries (Barach & Small, 2000; Dillon & Tinsley, 2008). However, the present study calls into question the ease with which meaningful learning from small failures can occur. Managers of organizations operating in high-hazard domains would do well to focus attention on attempts to draw knowledge from near-miss data, rather than assuming that safety improvement will flow naturally from collecting such data.

Limitations, Directions for Future Work, and Conclusion

The orbital launch industry provided a uniquely appropriate domain in which to examine learning from organizational success and failure but also presented a number of challenges that may limit the generalizability of our results. First, though we were able to control for the frequency of failures and successes in our supplementary analyses, we were unable to control for the differential costs of failed and successful launches. Because orbital launch vehicles are enormously costly to build, organizations may pay greater attention to failure in this domain than in other areas. If this is the case, the results may generalize most appropriately only to other domains in which the costs of failure are extremely high. Indeed, although this study failed to identify any significant organizational learning from success, we do not discount the possibility that it may occur in other settings. Future work could profitably examine organizational attempts to learn from success and better define the boundary conditions around such learning.

Second, because many of the organizations in our sample were government agencies (and all of them were secretive), we could not obtain data on organizational financial condition or expenditures on launch vehicle development. The fixed organization effects included in the analyses likely controlled for major interorganizational variation in financial resources, but we cannot rule out the possibility that unobserved organizational expenditures affected the results.

Third, because of the historical and international scope of our sample, as well as the secrecy practiced by many organizations in it, we were unable to collect data on organizational reactions to success and failure. Consequently, we were unable to systematically examine how learning efforts derived from failure differed from those derived from success, or to examine whether some postfailure learning practices produced more effective learning than others. But this limitation of the current work constitutes an important opportunity for future work. More research into the mechanisms by which organizations deal with and learn from failure is clearly needed. One very promising area for future research involves studying how organizations conduct incident reviews, accident investigations, and postmortems. These activities occur in many organizations with the explicit purpose of enabling them to learn from their failures. Although some scholars have called the value of these activities into doubt (Sagan, 1993), others have suggested their importance (Carroll, 1995; March et al., 1991). Additional studies could prove extremely important in determining whether and how the investigation process impacts learning through failure, and what characteristics of failure investigations encourage effective learning.

Fourth, it is implicit in our study's theoretical framework that organizational knowledge impacts organizational behavior. Consequently, we were unable to examine the possibility that experience may produce organizational knowledge that fails to have an impact on action. This may occur, for example, if knowledge is ignored or discarded prior to its use, or if new knowledge fails to disseminate effectively throughout an organization. The latter challenge may arise in large, complex organizations with highly differentiated external scanning and internal production functions. Future research should address these possibilities by directly examining the processes through which organizational knowledge arising through experience with successes and failures may affect or fail to affect organizational activities.

This study demonstrates that learning from large failures, rather than learning from success or small failures, primarily drives organizational improvement, at least in the orbital launch vehicle industry. It also shows that knowledge gleaned from failure persists longer than that developed through success and that different forms of prior experience drive organizational learning interactively. Collectively, the study's findings suggest the need to further explore organizational learning practices associated with failure and to determine how organizations may be able to reap the benefits of failure without exposing themselves to its costs.

REFERENCES

Abrahamson, E. 1996. Management fashion. ***Academy of Management Review,*** 21: 254–285.

Abrahamson, E., & Fairchild, G. 1999. Management fashion: Lifecycles, triggers, and collective learning processes. ***Administrative Science Quarterly,*** 44: 708–740.

Adler, P. S. 2001. Market, hierarchy, and trust: The knowledge economy and the future of capitalism. ***Organization Science,*** 12: 215–234.

Allison, P. D. 1999. ***Logistic regression using the SAS system: Theory and application.*** Cary, NC: SAS Institute Press.

Anand, V., Manz, C., & Glick, W. 1998. An organizational memory approach to information management. ***Academy Management Review,*** 23: 796–809.

Anderson, L. R., & Holt, C. A. 1997. Information cascades in the laboratory. ***American Economic Review,*** 87: 847–862.

Anton, J. J., & Yao, D. A. 2004. Little patents and big secrets: Managing intellectual property. ***Rand Journal of Economics,*** 35: 1–22.

Argote, L. 1999. ***Organizational learning: Creating, retaining, and transferring knowledge.*** Boston: Kluwer Academic.

Argote, L., Beckman, S. L., & Epple, D. 1990. The persistence and transfer of learning in industrial settings. ***Management Science,*** 36: 140–156.

Argote, L., & Epple, D. 1990. Learning curves in manufacturing. ***Science,*** 247: 920–924.

Arthur, J. B., & Huntley C. L. 2005. Ramping up the organizational learning curve: Assessing the impact of deliberate learning on organizational performance under gainsharing. ***Academy of Management Journal,*** 48: 1159–1170.

Arundel, A. 2001. The relative effectiveness of patents and secrecy for appropriation. ***Research Policy,*** 30: 611–624.

Audia, P. G., Locke, E. A., & Smith, K. G. 2000. The paradox of success: An archival and a laboratory study of strategic persistence following a radical environmental change. ***Academy of Management Journal,*** 43: 837–853.

Barach, P., & Small, S. D. 2000. Reporting and preventing medical mishaps: Lessons from non-medical near miss reporting systems. ***British Medical Journal,*** 320: 759–763.

Baum, J. A., & Dahlin, K. B. 2007. Aspiration performance and railroads' patterns of learning from train wrecks and crashes. ***Organization Science,*** 18: 368–385.

Baum, J. A., & Ingram, P. 1998. Survival-enhancing learning in the Manhattan hotel industry, 1898–1980. ***Management Science,*** 44: 996–1016.

Beckman, C., & Haunschild, P. 2002. Network learning: The effects of partners heterogeneity of experience on corporate acquisitions. ***Administrative Science Quarterly,*** 47: 92–124.

Benkard, C. L. 2000. Learning and forgetting: The dynamics of aircraft production. ***American Economic Review,*** 90: 1034–1054.

Bikhchandani, S., Hirshleifer, D., & Welch, I. 1992. A theory of fads, fashion, custom, and cultural change as informational cascades. ***Journal of Political Economy,*** 100: 992–1026.

Burger, J. M. 1981. Motivational biases in the attribution of responsibility for an accident: A meta-analysis of the defensive-attribution hypothesis. ***Psychological Bulletin,*** 90: 498–512.

CAIB. 2003. ***Columbia accident investigation board report,*** vol. 1. Washington, DC: U.S. Government Printing Office.

Cameron, K. S. 1984. The effectiveness of ineffectiveness. In B. M. Staw & L. L. Cummings (Eds.), ***Research in organizational behavior,*** vol. 6: 235–285. Greenwich, CT: JAI Press.

Cannon, M. D., & Edmondson A. C. 2001. Confronting failure: Antecedents and consequences of shared beliefs about failure in organizational work groups. ***Journal of Organizational Behavior,*** 22: 161–177.

Carroll, J. S. 1995. Incident reviews in high-hazard industries: Sensemaking and learning under ambiguity and accountability. ***Industrial and Environmental Crisis Quarterly,*** 9: 175–197.

Carroll, J. S. 1998. Organizational learning activities in high-hazard industries: The logics underlying self-analysis. ***Journal of Management Studies,*** 35: 699–717.

Chuang, Y. T., & Baum, J. A. C. 2003. It's all in the name: Failure-induced learning by multiunit chains. ***Administrative Science Quarterly,*** 48: 33–59.

Cohen, W., & Levinthal, D. 1990. Absorptive capacity: A new perspective on learning and innovation. ***Administrative Science Quarterly,*** 35: 128–152.

Cohen, W., & Levinthal, D. 1994. Fortune favors the prepared firm. ***Management Science,*** 40: 227–251.

Conner, K. R. 1991. A historical comparison of resource-based theory and five schools of thought within industrial organization economics: Do we have a new theory of the firm? ***Journal of Management,*** 17: 121–154.

Cyert, R. M., & March, J. G. 1963. ***A behavioral theory of the firm.*** Englewood Cliffs, NJ: Prentice Hall.

Daft, R. L., & Weick, K. E. 1984. Toward a model of organizations as interpretation systems. ***Academy Management Review,*** 9: 284–295.

Darr, E., Argote, L., & Epple, D. 1995. The acquisition, transfer, and depreciation of knowledge in service organizations: Productivity in franchises. ***Management Science,*** 31: 1750–1762.

Davis, G. F. 1991. Agents without principles—The spread of the poison pill through the intercorporate network. ***Administrative Science Quarterly,*** 36: 583–613.

De Holan, P. M., & Phillips, N. 2004. Remembrance of things past? The dynamics of organizational forgetting. ***Management Science,*** 50: 1603–1613.

Denrell, J. 2003. Vicarious learning, undersampling of failure, and the myths of management. ***Organization Science,*** 14: 227–243.

Dillon, R. L., & Tinsley, C. H. 2008. How near-misses influence decision making under risk: A missed opportunity for learning. ***Management Science,*** 54: 1425–1440.

Edmondson, A. 1999. Psychological safety and learning behavior in work teams. ***Administrative Science Quarterly,*** 44: 350–383.

Eisenhardt, K., & Martin, J. 2000. Dynamic capabilities: What are they? ***Strategic Management Journal,*** 21: 1105–1121.

Elsbach, K. D. 1994. Managing organizational legitimacy in the California cattle industry—The construction and effectiveness of verbal accounts. ***Administrative Science Quarterly,*** 39: 57–88.

Epple, D., Argote, L., & Devadas, R. 1991. Organizational learning curves: A method for investigating intraplant transfer of knowledge acquired through learning by doing. ***Organization Science,*** 2: 58–70.

Felin, T., & Hesterly, W. S. 2007. The knowledge-based view, nested heterogeneity, and new value creation: Philosophical considerations on the locus of knowledge. ***Academy of Management Review,*** 32: 195–218.

Florida Today. 1997. Delta cleared for launch but explosion probe continues. May 1: A2.

Ford, J. D. 1985. The effects of causal attributions on decision makers' responses to performance downturns. ***Academy of Management Review,*** 10: 770–786.

Grant, R. M. 1996. Toward a knowledge-based theory of the firm. ***Strategic Management Journal,*** 17: 109–122.

Greve, H. R. 2003. ***Organizational learning from performance feedback.*** New York: Cambridge University Press.

Groysberg, B., Lee, L. E., & Nanda, A. 2008. Can they take it with them? The portability of star knowledge workers' performance. ***Management Science,*** 54: 1213–1230.

Hannan, M. T., & Carroll, G. R. 1992. ***Dynamics of organizational populations: Density, legitimation, and competition.*** New York: Oxford University Press.

Haunschild, P. R., & Miner, A. S. 1997. Modes of interorganizational imitation: The effects of outcome salience and uncertainty. ***Administrative Science Quarterly,*** 42: 472–500.

Haunschild, P. R., & Rhee, M. 2004. The role of volition in organizational learning: The case of automotive product recalls. ***Management Science,*** 50: 1545–1560.

Haunschild, P. R., & Sullivan, B. N. 2002. Learning from complexity: Effects of prior accidents and incidents on airlines' learning. ***Administrative Science Quarterly,*** 47: 609–643.

Haveman, H. A., & Cohen, L. E. 1994. The ecological dynamics of careers—The impact of organizational founding, dissolution, and merger on job mobility. ***American Journal of Sociology,*** 100: 104–152.

Hayward, M. L. 2002. When do firms learn from their acquisition experience? Evidence from 1990–1995. ***Strategic Management Journal,*** 23: 21–39.

Hayward, M. L., Rindova, V. P., & Pollock, T. G. 2004. Believing one's own press: The causes and consequences of CEO celebrity. ***Strategic Management Journal,*** 25: 637–653.

Hirsch, W. Z. 1952. Manufacturing progress functions. ***Review of Economics and Statistics,*** 34: 143–155.

Hoffman, A. J., & Ocasio, W. 2001. Not all events are attended equally: Toward a middle-range theory of industry attention to external events. ***Organization Science,*** 12: 414–434

Huber, G. P. 1991. Organizational learning: The contributing processes and the literatures. ***Organization Science,*** 2: 88–115.

Huckman, R. S., & Pisano, G. P. 2006. The firm specificity of individual performance: Evidence from cardiac surgery. ***Management Science,*** 52: 473–488.

Ingram, P., & Baum, J. A. 1997. Chain affiliation and the failure of Manhattan hotels, 1898–1980. ***Administrative Science Quarterly,*** 42: 68–102.

Judge, G. G., Griffiths, W. E., Hill, R. C., Lutkepohl, H., & Lee T. C. 1985. ***The theory and practice of econometrics*** (2nd ed.). New York: Wiley.

Katila, R., Rosenberger, J. D., & Eisenhardt, K. M. 2008. Swimming with sharks: Technology ventures, defense mechanisms and corporate relationships. ***Administrative Science Quarterly,*** 53: 295–332.

Kim, J. Y. 2000. ***Crash test without dummies: A longitudinal study of interorganizational learning from failure experience in the U.S. commercial banking industry, 1984–1998.*** Unpublished doctoral dissertation, University of Wisconsin–Madison.

Kim, J. Y., & Miner, A. S. 2007. Vicarious learning from the failures and near-failures of others: Evidence from the U.S. commercial banking industry. ***Academy of Management Journal,*** 50: 687–714

Kogut, B., & Zander, U. 1996. What firms do? Coordination, identity, and learning. ***Organization Science,*** 7: 502–518.

Kraatz, M. S., & Moore, J. H. 2002. Executive migration and institutional change. ***Academy of Management Journal,*** 45: 120–143.

Langer, E. J. 1989. ***Mindfulness.*** Reading, MA: Addison-Wesley.

Lant, T. K. 1992. Aspiration level adaptation: An empirical exploration. ***Management Science,*** 38: 623–644.

Launius, R. D., & Jenkins, D. R. 2002. ***To reach the high frontier.*** Lexington: University Press of Kentucky.

Levinthal, D., & March, J. G. 1981. A model of adaptive organizational search. ***Journal of Economic Behavior and Organization,*** 2: 307–333.

Levinthal, D., & March, J. G. 1993. The myopia of learning. ***Strategic Management Journal,*** 14: 95–112.

Levitt, B., & March, J. G. 1988. Organizational learning. In W. R. Scott (Ed.), ***Annual review of sociology,*** vol. 14: 319–340. Palo Alto, CA: Annual Reviews.

Louis, M. R., & Sutton, R. I. 1991. Switching cognitive gears: From habits of mind to active thinking. ***Human Relations,*** 44: 55–76.

Madsen, P., Desai, V., Roberts, K., & Wong, D. 2006. Mitigating hazards through continuing design: The birth and evolution of a pediatric intensive care unit. ***Organization Science,*** 17: 239–248.

Manski, C. F. 1993. Identification of endogenous social effects: The reflection problem. ***Review of Economic Studies,*** 60: 531–542.

March, J. G. 1981. Footnotes to organizational change. ***Administrative Science Quarterly,*** 26: 563–577.

March J. G. 1991. Exploration and exploitation in organizational learning. ***Organization Science,*** 2: 71–87.

March, J. G., & Olsen, J. P. 1976. ***Ambiguity and choice in organizations.*** Bergen, Norway: Universitetsforlaget.

March J. G., & Shapira, Z. 1992. Variable risk preferences and the focus of attention. ***Psychological Review,*** 99: 172–183.

March, J. G., & Simon, H. 1958. ***Organizations.*** New York: Wiley.

March, J. G., Sproull, L. S., & Tamuz, M. 1991. Learning from samples of one or fewer. ***Organization Science,*** 2: 1–14.

Miner, A. S., & Haunschild, P. R. 1995. Population level learning. In L. L. Cummings & B. M. Staw (Eds.), ***Research in organizational behavior,*** vol. 17: 115–166. Greenwich, CT: JAI Press.

Miner, A. S., Kim, J., Holzinger, I. W., & Haunschild, P. 1999. Fruits of failure: Organizational failure and population-level learning. In A. S. Miner & P. Anderson (Eds.), ***Advances in strategic management,*** vol. 16: 187–220. Greenwich, CT: JAI Press.

Morris, M. W., & Moore, P. C. 2000. The lessons we (don't) learn: Counterfactual thinking and organizational accountability after a close call. ***Administrative Science Quarterly,*** 45: 737–765.

Nelson, R. R., & Winter, S. G., 1982. ***An evolutionary theory of economic change.*** Cambridge, MA: Belknap.

Pisano, G. P., Bohmer, R. M., & Edmondson, A. C. 2001. Organizational differences in rates of learning: Evidence from the adoption of minimally invasive cardiac surgery. ***Management Science,*** 47: 752–768.

Rapping, L. 1965. Learning and World War II production functions. ***Review of Economics and Statistics,*** 47: 81–86.

Ross, L., Greene, D., & House, P. 1976. The "false consensus effect": An egocentric bias in social perception and attribution processes. ***Journal of Experimental Social Psychology,*** 13: 279–301.

Ross, M., & Sicoly, F. 1979. Egocentric biases in availability and attribution. ***Journal of Personality and Social Psychology,*** 37: 322–336.

Sagan, S. D. 1993. The ***limits of safety: Organizations, accidents, and nuclear weapons.*** Princeton, NJ: Princeton University Press.

Schein, E. H. 1985. ***Organizational culture and leadership.*** San Francisco: Jossey-Bass.

Simon, H. 1991. Bounded rationality and organizational learning. ***Organization Science,*** 2: 125–134.

Sitkin, S. B. 1992. Learning through failure: The strategy of small losses. In B. M. Staw & L. L. Cummings (Eds.), ***Research in organizational behavior,*** vol. 14: 231–266. Greenwich, CT: JAI Press.

Staw, B. M., & Ross, J. 1987. Behavior in escalation situations-antecedents, prototypes, and solutions. In L. L. Cummings & B. M. Staw (Eds.), ***Research in organizational behavior,*** vol. 9: 39–78. Greenwich, CT: JAI Press.

Strang, D., & Macy, M. W. 2001. In search of excellence: Fads, success stories, and adaptive emulation. ***American Journal of Sociology,*** 107: 147–182.

Suchman, M. C. 1995. Managing legitimacy—Strategic and institutional approaches. ***Academy of Management Review,*** 20: 571–610.

Tax, S. S., & Brown, S. W. 1998. Recovering and learning from service failure. ***Sloan Management Review,*** 40(1): 75–88.

Thompson, P. 2007. How much did the liberty shipbuilders forget? ***Management Science,*** 53: 908–918.

Turner, B. A. 1978. ***Man-made disaster.*** London: Wykeham.

Vaughan, D. 1996. ***The Challenger launch decision.*** Chicago: University of Chicago Press.

Vaughan, D. 2005. System effects: On slippery slopes, repeating negative patterns, and learning from mistake? In M. Farjoun & W. Starbuck (Eds.), ***Organization at the limit: NASA and the Columbia disaster.*** Oxford, U.K.: Blackwell.

Walsh, J. P., & Ungson, G. R. 1991. Organizational memory. ***Academy of Management Review,*** 16: 239–270.

Wegner, D. M. 1986. Transactive memory: A contemporary analysis of the group mind. In G. Mullen & G. Goethals (Eds.), ***Theories of group behavior:*** 185–208. New York: Springer-Verlag.

Weick, K. E. 1979. ***The social psychology of organizing*** (2nd ed.). Reading, MA: Addison-Wesley.

Weick, K. E. 1984. Small wins: Redefining the scale of social problems. ***American Psychologist,*** 39: 40–49.

Weick, K. E., & Roberts, K. H. 1993. Collective mind in organizations: Heedful interrelating on flight decks. ***Administrative Science Quarterly,*** 38: 357–381.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. 1999. Organizing for high reliability: Processes of collective mindfulness. In B. M. Staw & R. Sutton (Eds.), ***Research in organizational behavior,*** vol. 21: 81–123. Greenwich, CT: JAI Press.

Wildavsky, A. 1988. ***Searching for safety.*** New Brunswick, NJ: Transaction Books.

Zellmer-Bruhn, M. E. 2003. Interruptive events and team knowledge acquisition. ***Management Science,*** 49: 514–528.

Zucker, L. G. 1987. Institutional theories of organization. In W. R. Scott & J. F. Short (Eds.), ***Annual review of sociology,*** vol. 13: 443–464. Palo Alto, CA: Annual Reviews.

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