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How Near-Misses Influence Decision Making Under Risk: A Missed Opportunity for Learning

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Although organizations appear to learn from obvious failures, we argue that it is harder for them to learn from "near-misses"—events in which chance played a role in averting failure. In this paper, we formalize the concept of near-misses and hypothesize that organizations and managers fail to learn from near-misses because they evaluate such events as successes and thus feel safer about the situation. We distinguish *perceived* ("felt") risk from calculated *statistical* risk and propose that lower levels of perceived risk encourage people with near-miss information to make riskier subsequent decisions compared to people without near-miss information. In our first study, we confirm the tendency to evaluate near-misses as successes by having participants rate a project manager whose decisions result in either (a) mission success, (b) near-miss, or (c) failure. Participants (both students and NASA employees and contractors) give similar ratings to managers whose decisions produced near-misses and to managers whose decisions resulted in successes, and both ratings are significantly different from ratings of managers who experienced failures. We suggest that the failure to hold managers accountable for near-misses is a foregone learning opportunity for both the manager and the organization. In our second set of studies, we confirm that near-miss information leads people to choose a riskier alternative because of a lower perceived risk following near-miss events. We explore several alternative explanations for these findings, including the role of Bayesian updating in processing near-miss data. Ultimately, the analysis suggests that managers and organizations are reducing their perception of the risk, although not necessarily updating (lowering) the statistical probability of the failure event. We speculate that this divergence arises because perceived risk is the product of associative processing, whereas statistical risk arises from rule-based processing.

Key words: risk; inference; decision making
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> The shedding of External Tank foam—the physical cause of the *Columbia* accident—had a long history . . . . [It] occurred on every Space Shuttle flight, raising an obvious question: Why did NASA continue flying the Shuttle with a known problem that violated design requirements? It would seem that the longer the Shuttle Program allowed debris to continue striking the Orbiters, the more opportunity existed to detect the serious threat it posed. But this is not what happened . . . With each successful landing, it appears that NASA engineers and managers increasingly regarded the foam-shedding as inevitable, and as either unlikely to jeopardize safety or simply an acceptable risk.
>
> (*Columbia* Accident Investigation Board, pp. 121–122)

1. Introduction

Near-misses—successful outcomes in which chance plays a critical role in averting failure—are a common phenomenon, although infrequently studied in management research. As the above quotation suggests, many Space Shuttle missions prior to the *Columbia* disaster should be characterized as near-misses. The missions were "misses" because failure was forestalled, yet "near" because only chance prevented the failed outcome. Specifically, foam from the left bipod ramp of the external tank was shed on at least 30 previous shuttle missions; again and again, disaster was averted only because the foam did not hit a sensitive portion of the orbiter. NASA documentation prior to the *Columbia* disaster depicts probability distributions for failure from debris strikes (see Paté-Cornell and Fischbeck 1994), and shows that a statistical probability of failure was both known and acknowledged. Nonetheless, the *Columbia* Accident Investigation Report (2003) indicates that NASA management grew complacent regarding the frequent foam shedding. We suggest that the foam strikes, or near-misses, lowered NASA managers' perceived (or "felt") risk, leading to complacency rather than urgency. As the *Columbia* disaster shows all too well, near-misses are not simply curiosities worthy of grateful relief, but rather presages of future failures worthy of targeted scientific inquiry.

Prior research has argued that organizational systems emit warning events that *should* be viewed as opportunities to evaluate the resilience of the system so as to avoid future failure (Carroll 2003, Turner 1976, March et al. 1991). However, this largely normative approach fails to address why such evaluations rarely occur. In this paper, we explain why people may fail to learn from near-misses by analyzing how the events are interpreted and the subsequent impact on perceived risk.

Learning from past events is complicated by the hindsight bias—the tendency, after the fact, to overestimate the amount of information one thought relevant at the time a decision was made (Gephart 1993, Fischhoff 1975, Fischhoff and Beyth 1975). Thus, the hindsight bias suggests that only after a catastrophe do people see the warnings embedded in near-miss events. Our experiments, however, indicate that people do not ignore near-miss events at the time of decision making. Rather, our first study reveals that people acknowledge near-misses, recognizing these events as chance successes (that outcome X occurred, but that the alternative X' could have occurred), but, consistent with an outcome bias (Baron and Hershey 1988), evaluate the near-miss similarly to a success. Because of such interpretations, managers whose decisions result in near-misses are not held accountable for potentially problematic decision making. In our second set of studies, we give people information about the probability of failure, which we call *statistical risk*—the quantitative likelihood of a hazard occurring and its consequences. We find that, relative to people without near-miss information, those with information about prior near-misses lower their *perceived risk*—how risky they felt the situation was, even while their assessment of the statistical risk remains unchanged. Given the same level of statistical risk, people with near-miss information are more optimistic about the chance of success for that statistical risk than those without near-miss information, and thus are apt to take the risk.

Kahneman and Varey (1990) offer a framework for distinguishing between events that almost happen versus events that could have happened. They define an event's disposition (i.e., the statistical probability of an event occurring based on prior base-rate information) and an event's propensity (i.e., the perceived likelihood of the event occurring based on event cues). Near-misses where failure could have occurred but did not almost occur have a disposition for failure, but not always an equivalent propensity for such failure.[1] As such, exposure to near-miss events can influence perceived or felt risk in different ways even when these events do not alter statistical probability estimates as they would in a Bayesian analysis. Our concern is that if near-misses decrease perceived risk, they will encourage riskier future choices.

Returning to the example of *Columbia*, because the prior foam debris did not "almost" cause a failure (i.e., exhibit clear signs of a propensity for failure such as clear burn marks from reentry around the damaged tiles), NASA managers categorized these near-misses as successful missions despite an existing disposition for a catastrophic failure. Thus, NASA managers paid attention to the near-misses and regularly repaired the debris damage after missions, yet appeared to experience less felt risk (cf. Vaughan's 1996 discussion of the "normalization of deviance"). We argue that this lower sense of perceived risk encouraged future riskier choices—to continue launching the shuttle despite the known problems. Hence, NASA managers contemporaneously accounted for, but failed to learn from, near-misses.

In the next section, we formally define a near-miss. In §3, we demonstrate that people tend to evaluate near-misses similar to successes rather than failures and, furthermore, that managers whose decisions result in near-misses are judged like managers whose decisions result in success, and significantly more favorably than managers who experience failures. In §4, we show that people with near-miss information are more likely to choose a risky option rather than play it safe, and we explore several explanations for this phenomenon. In §5, we offer alternative interpretations of near-miss events that might improve decision making and learning.

2. Defining Near-Misses

The definition of a near-miss varies across researchers. Some, for example, define a near-miss as when an event *almost* happens—for example, when a slot machine displays two of the three symbols necessary to win a payout (Dixon and Schreiber 2004), or an audience member at a concert almost wins a free vacation but does not because she switched seats at the last minute (Kray et al. 2006). Others, particularly in the fields of medicine (cf. Seki and Yamazaki 2006, Rosenthal et al. 2005, Barger et al. 2005) and risk analysis (Phimister et al. 2003, Kaplan 1990, Paté-Cornell 2004, DeJoy 1990, DeJoy and Klippel 1984), define a near-miss as when an event *could have* happened (for example, because of hazardous conditions) but did not. In systems analysis, for example, "safety pyramids" (Phimister et al. 2003) show a typical distribution of data, with a few injuries at the top of the pyramid and many near-misses at its foundation that represent anomalous incidents under hazardous conditions in which an injury could have occurred but

[1] Consider a roulette wheel where each number has an equal probability of being chosen (i.e., the number's disposition). However, if the ball ends up in the vicinity of the number 4 a few times, the roulette wheel may be characterized as having more of a propensity for the number 4 than a number on the far side of the wheel.

did not. Our definition of a near-miss as a chance success is consistent with the phenomena studied by other systems researchers. We do not include nominal near-misses that result when purposeful last-minute managerial action averts crisis, nor "chance failures" when chance contributes to a *failure* outcome (cf. Kray et al. 2006).

Kahneman and Varey (1990) argue that events that *could have* happened are cognitively distinct from events that *almost* happened and are likely to be processed differently. Specifically, they argue that whereas events that *almost* happened can trigger counterfactual thinking (Kahneman and Varey 1990), which should induce learning (cf. McMullen 1997, Markman and Tetlock 2000, Kray and Galinsky 2003), near-misses that *could have* happened may not trigger this learning. Our intent is to explore why many near-miss events do not inspire learning. Our thesis is that people tend to interpret near-miss events, defined as failures that *could have* happened but did not, as successes, thereby lowering perceived risk and increasing comfort with statistically risky decisions.

Imagine, for example, that you are part of a research group that regularly meets in a bad part of town.[2] You check recent crime statistics on the Web and learn there has been a mugging within the vicinity of your meeting roughly every 40 days during the hours you would be visiting, leading you to estimate the statistical risk of someone being mugged on your meeting day is 2.5%. Given this statistical risk, you feel your attendance at the meeting to be a somewhat risky decision. After attending five group meetings without incident, however, you begin to feel safer in that neighborhood. You do not necessarily update your statistical risk by reestimating a lower mugging rate for the block. You simply feel differently about that 2.5%; your perceived risk is lowered; your decision to attend the meetings feels less risky. You know that on any of those prior five visits a mugging *could have* happened, but these near-misses lower your perceived risk. Alternatively, imagine you had almost been the victim of a mugging—perhaps you learned that someone had been mugged on that block during your meeting time the very next day. This *almost* near-miss might trigger a very different cognitive process and a very different perception of the statistical risk. Here, we focus on events that *could have* happened but did not *almost* happen. Near-misses as events where failure *could have* happened but did not are not likely to trigger learning and, indeed, may even be processed as successes, rather than chance-contingent successes. We investigate this first proposition below.

[2] We are grateful to a risk analysis colleague who provided this story based on her own experience.

3. Near-Miss Events and the Outcome Bias

Because organizational outcomes are rarely predetermined, failure is often a possibility. Organizations must tolerate some risk of failure, such as when the costs of lowering that risk further are prohibitively expensive. As managers make decisions over time, outcomes result in part from decisions and in part from chance. However, it is difficult to monitor managerial actions (Jensen and Meckling 1976), and as the ambiguity and novelty of the decision environment increases, so does the difficulty of judging managerial decision quality. Thus, evaluations tend to be heavily anchored on outcomes (Baron and Hershey 1988).

Near-misses offer evidence of both a system's resilience (failure averted) and its vulnerability (failure narrowly averted) (March et al. 1991). Therefore, a near-miss resembles a success in terms of ultimate outcome, but resembles a failure in other details, such as problems arising before the outcome. However, consistent with outcome bias (Baron and Hershey 1988), we believe that decision makers will evaluate a near-miss like a success based on the ultimate outcome. Thus, we expect near-misses to be judged in a similar manner as successes and in a significantly different manner from failures despite the fact that such near-misses would have been failures except for an element of chance.

Hypothesis 1. *Both near-miss outcomes and success outcomes will be judged significantly more successful than failure outcomes.*

The outcome bias (Baron and Hershey 1988) dampens organizational learning because it causes evaluators to focus only on outcomes and to overweight the contribution of managers' decisions to organizational outcomes (Allison et al. 1996). As a result, organizational successes do not get the scrutiny they deserve, and failures may receive too much attention. If this is true, we expect that the decisions of managers that result in near-misses will be judged as favorably as those of managers whose decisions result in successes and significantly better than the decisions of managers whose decisions result in failures. Moreover, because character traits are generally presumed to be consistent (Sedikides and Anderson 1994), the overall character (competence, intelligence, leadership, promotability, and so on) of managers whose decisions result in near-misses will be judged as favorably as the character of managers whose decisions result in successes, and significantly better than the character of managers whose decisions result in failures.

Hypothesis 2. *Both managers whose decisions result in a near-miss and those whose decisions result in a success will be evaluated more favorably than managers whose decisions result in a failure.*

Table 1 Experiment 1: Pearson Correlations Between Control and Dependent Variables

	Age	Gender	Decision ability	Competence	Intelligence	Leadership	Larger project	Outcome	Surprised
Age	1								
Gender	−0.07	1							
Decision ability	−0.10	−0.02	1						
Competence	−0.10	0.08	0.42**	1					
Intelligence	−0.05	−0.02	0.40**	0.70**	1				
Leadership	0.05	−0.02	0.60**	0.50**	0.47**	1			
Larger project	−0.04	−0.09	0.47**	0.46**	0.45**	0.48**	1		
Outcome[a]	−0.30	−0.02	0.53**	0.51**	0.38*	0.45**	0.47**	1	
Surprised	0.17	0.51**	0.17	0.12	−0.31	−0.07	−0.21	0.19	1

[a]Rating of outcome from 1 = failure to 7 = success.
*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

Moreover, we propose that the evaluation of near-miss events as successes explains why managers whose decisions result in a near-miss will be evaluated as favorably as those whose decisions result in success and significantly better than those whose decisions result in failure.

Hypothesis 3. *The differences in participants' evaluations of managers across conditions can be explained* (*mediated*) *by participants' judgments of the outcome*.

3.1. Method: Materials, Participants, and Procedures

To test whether near-misses are judged to be more similar to successes than to failures, we created three descriptions of an organizational project in which Chris, the project manager, makes a series of decisions that result in either: (1) a mission success, (2) a failure, or (3) a near-miss. The project is the development of an unmanned spacecraft, and our participants were students and NASA personnel. In all versions, Chris makes the same decisions: because of turnover and tight schedules, Chris decides to skip a peer review of the instrument and decides not to investigate a last-minute, potentially catastrophic (albeit low-probability) design problem. In the failure version, participants read that an error occurred shortly after launch and that, "By chance, the spacecraft's random alignment to the sun caused all of the solid hydrogen to convert to a gas and vent at an extremely high rate;" this problem was catastrophic to the mission. In the near-miss version, the same problem occurs, but, "By chance, because the spacecraft's random alignment to the sun shaded the instrument from the sun's rays, the solid hydrogen converted to a gas at a slow rate producing no destabilizing force on the spacecraft;" thus, the problem was not catastrophic to the mission.[3] In the success version, no error after launch is mentioned, and participants read that the spacecraft is sending back useful data (see the appendix for the full text of cases). Participants read only one of these versions and then evaluated, on a 7-point Likert scale, Chris': decision ability, competence, intelligence, leadership, and promotability to a larger project. A later version ($N = 61$) of the materials also asked participants to rate the outcome of the mission on a 1–7 Likert scale ranging from 1 = failure to 7 = success, and to rate how surprised they were about the outcome with 1 = not at all surprised and 7 = very surprised.

Data were collected from three groups of participants: NASA managers ($N = 71$), MBA students ($N = 63$), and undergraduate ($N = 158$) business students from a large Eastern U.S. university. NASA managers participated as part of a training course on project management. The students filled out the exercise as part of their classroom activities during a lesson on general decision making.

3.2. Analysis and Results

Bivariate correlation showed that, as expected, the dependent variables are significantly correlated with each other (see Table 1), thus multivariate analysis of variance (MANOVA) is used (Devore 1987), with condition (success, near-miss, failure) and sample (NASA, MBA, Undergraduate) as the independent variables. Condition has a significant effect on the dependent variables (Wilks' $\text{Lambda}_{(10,\,450)} = 3.95$, $p < 0.001$). There is no significant effect for sample or the interaction of sample by condition, the latter of which suggests that the pattern of responses, by condition, did not differ across samples. Thus, we present the results from all participants together.[4]

Condition has a significant effect on how the outcome of the mission is coded by participants and

[3] We are grateful to reviewers who suggested this wording as more neutral than our original materials, which used "fortunately/unfortunately" rather than "by chance." We made this change and collected additional data from 61 participants. We found no significant differences between the two data sets, and thus report all data together.

[4] Disaggregated tests are available from the authors upon request.

Table 2 Experiment 1: Means, Standard Deviations, and Contrasts of Evaluations by Condition

Dependent variables	Success		Near-miss		Failure		Effect for condition	Success/ Failure	Success/ Near-miss	Near-miss/ Failure
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	$F_{(2, 229)}$	p-value*	p-value*	p-value*
Outcome[a]	4.53	1.79	5.44	2.32	1.75	2.32	30.9[b]	<0.001	n.s.	<0.001
Surprised	3.45	1.90	5.22	2.12	3.75	2.45	6.15[b]	n.s.	<0.005	<0.01
Decision ability	4.62	1.66	4.46	1.48	3.82	1.70	5.58	0.002	n.s.	<0.01
Competence	4.64	1.32	4.56	1.15	3.80	1.32	10.67	<0.001	n.s.	0.001
Intelligence	4.54	1.34	4.53	1.28	4.10	1.40	2.56	0.04	n.s.	0.07
Leadership	5.29	1.24	4.91	1.46	4.38	1.65	8.43	<0.001	n.s.	<0.05
Promote to larger project	3.94	1.54	3.75	1.54	2.83	1.51	12.24	<0.001	n.s.	<0.001

[a]Rating of outcome from 1 = failure to 7 = success.
[b]Degrees of freedom for this F test are (2, 33).
*Significance according to post hoc Tukey HSD, one- tailed test. n.s., not significant.

how surprised participants are with the outcome. Post hoc contrasts, using the Tukey HSD, tested which of our three conditions (success, failure, or near-miss) are significantly different from each other. Results, detailed in Table 2, support Hypothesis 1. Specifically, when asked to evaluate the outcome of the mission, participants do not rate the near-miss event as significantly different from the success, and rate both the near-miss (mean = 5.44, s.d. = 2.32) and the success (mean = 4.53, s.d. = 1.79) significantly higher than the failure (mean = 1.75, s.d. = 2.32) outcome. As well, participants are significantly more surprised by the outcome in the near-miss condition (mean = 5.22, s.d. = 2.12) than in either the success (mean = 3.45, s.d. = 1.90) or failure (mean = 3.75, s.d. = 2.45) condition. Thus, they consider a near-miss to be a successful outcome, but their level of surprise suggests some acknowledgment that failure could have occurred.

Univariate F statistics show that condition has a significant effect on decision ability, competence, leadership ability, intelligence, and the decision to promote the manager to a larger project. Post hoc contrasts, detailed in Table 2, support Hypothesis 2. Namely, for all characteristics (decision ability, competence, intelligence, leadership ability, and promotability), managers whose decisions resulted in a either a success or near-miss are rated significantly more favorably than managers whose decisions resulted in a failure, although the results for intelligence are only marginally significant.

Finally, we use hierarchical regression to examine whether participants' evaluations of the outcome and their level of surprise mediated participants' ratings of managers' decision ability, competence, intelligence, leadership, and promotability. Following James and Brett (1984), we assess (1) whether the mediators are a probabilistic function of the independent variables, (2) whether the dependent variables are a probabilistic function of the mediators, and (3) how the addition of the independent variables to Step 2 changes the variance explained in the dependent variables.[5] Full mediation occurs when the addition of the independent variables does not explain any additional variance in the dependent variables than what the mediators explained (that is the change in R-squared (R^2) from Step 2 to Step 3 is not significant). If the change in R^2 from Step 2 to Step 3 is significant then partial mediation is a possibility.

MANOVA results in Table 2 (rows 3 and 4) show that the mediators (evaluation of outcome and surprise) are a probabilistic function of condition. Table 3, Model 1 shows that the dependent variables are a probabilistic function of the mediators. With age and gender as controls, regression of the dependent variables on the mediators show "evaluations of outcome" has a significant effect on all the dependent variables (decision ability, competence, intelligence, leadership, and promotability), and "surprise" influences both intelligence and promotability. Table 3, Model 2 shows how the addition of the independent variable (condition) influences Model 1. Specifically, condition did not generally explain any additional variance in the dependent variables over and above what was already explained by the mediating variables. The exception is the significant change in R^2 for intelligence. This suggests that, as hypothesized, outcome ratings fully mediate (or explain) the variance in participants' ratings of managers for decision ability, competence, leadership ability, and promotability, so that Hypothesis 3 is largely supported.

3.3. Discussion

Our data show that managers whose decisions resulted in a near-miss, like managers whose decisions resulted in success, are evaluated more favorably than

[5] Testing whether the independent variables have a significant influence on the dependent variables is often done as well (Baron and Kenny 1986), but is not required. We did this with the MANOVA, and Table 2, rows 5–9 show this influence.

Table 3 **Experiment 1: Mediation Analyses Using Hierarchical Regression**

	Decision ability		Competence		Intelligence		Leadership		Larger project	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Step 1 (controls)										
Age	0.08[b]	0.13	0.07	0.14	0.06	0.18	−0.01	0.06	0.19	0.20
Gender	−0.17	−0.16	0.29	0.29	0.03	0.03	−0.25	−0.25	−0.01	−0.01
Step 2 (mediators)										
Outcome (failure versus success)	0.54***	0.96***	0.59***	0.99***	0.48**	0.99***	0.47**	0.92**	0.60***	0.71**
Surprised	0.06	0.22	−0.20	−0.05	−0.37+	−0.38+	−0.17	−0.10	−0.38*	−0.36+
Adj. R^2	0.21**		0.24**		0.17*		0.25*		0.29**	
Step 3 (indep. vars.)										
Success[a]		0.44		0.42+		0.06		0.22		0.08
Failure		0.71		0.73*		0.73+		0.63+		0.16
Adj. R^2		0.30**		0.33**		0.28*		0.29*		0.29*
Change in R^2		0.09+		0.09+		0.11*		0.04		0.0
Change $F_{(2,31)}$		2.7		2.8		3.3		1.7		0.12
P(change)		0.08		0.08		0.05		0.19		0.89

[a]Condition dummy coded with near-miss as the reference category.
[b]Standardized regression coefficient.
$^{+}p < 1.0$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

those whose decisions resulted in a failure. These evaluations occur because of how managers judge near-miss outcomes—as successes rather than failures. Because prior research shows that past successes contribute to overconfidence and over-optimism in future decision making, interpreting near-misses as successes can be antithetical to organizational learning (Kahneman and Lovallo 1993, Hilary and Menzly 2006, Lowe and Ziedonis 2006).

Note that although near-miss outcomes are evaluated as successes, participants express significantly more surprise with these outcomes than with successes. This suggests that participants in the near-miss case did not see successful resolution as a foregone, predetermined outcome; rather, their surprise acknowledges some role of chance in the successful resolution. That is, they recognize that the manager has accepted some statistical risk, and so are more surprised by the positive outcome than in the success condition. However, it is possible that this statistical risk is not the only type of risk affecting people's judgments and behaviors. Specifically, we propose that people assess both a statistical risk and a perceived risk, which is how they feel about the calculated statistical risk. Although both types of risk may influence behavior, they themselves may be differentially influenced by antecedent events. As our anecdote about the research meeting in a bad part of town is meant to illustrate, near-miss events could decrease someone's level of perceived risk without necessarily affecting their statistical risk. Thus, people with near-miss information could experience a lower level of perceived risk for the same level of statistical risk, compared to people without near-miss information. This suggests that people with near-miss information should be more likely to choose risky options than their counterparts without this information. We test these ideas in the experiments that follow.

4. How Near-Miss Information Influences Decisions Under Risk

In theory, near-misses can be soberly evaluated as warnings of future failure or celebrated as instances in which failure is averted. In reality, as our first study shows, near-misses, like successes, tend to be evaluated significantly better than failures. This finding is consistent with the outcome bias; when interpreting near-miss events, participants are more influenced by what did occur (a successful mission) than by what might have occurred (a chance of failure).

This finding is also consistent with Kahneman and Varey's (1990) theory about event propensity and counterfactual thought. According to their framework, events (such as a failure) with a disposition that *could have* happened evoke different cognitions from events with a propensity that *almost* happened. Although events that *almost* happened will generally invoke a counterfactual mindset, which should trigger critical evaluation and learning (Markman and Tetlock 2000, Kray et al. 2006), near-miss events that *could have* happened do not necessarily create a close counterfactual thought, even if they have a high disposition toward failure (here a high statistical risk of failure). In fact, Kahneman and Varey (1990), show that people come to process dispositional expectations that are not confirmed by event cues with less relevance, thus resulting in "disposition neglect" (related to the neglect of base-rate information, cf. Bar-Hillel 1980, Massey and Wu 2005). People do not necessarily ignore dispositional (statistical probability) information, but might underweight it in their decision making, relative to signals about propensity.

If an event's disposition is its statistical probability of occurring and its propensity is related to its perceived possibility of occurring, then we suggest that near-miss events that do not exhibit any propensity toward failure (in the form of event cues that suggest failure is proximal) should decrease the level of risk someone perceives or feels in the situation (even if statistical probabilities about failure remain constant). Hence, we believe that decision makers often fail to learn from near-miss events when these events evince little propensity. Rather, exposure to low-propensity near-miss events should lead decision makers to feel differently about the statistical risks involved in the situation. As the calculated level of statistical risk feels "less risky," decision makers should be more likely to choose this risky option rather than a safe option, compared to people who do not have near-miss information. Our basic proposition is:

Hypothesis 4. *Compared to people with no information about near-misses, people with information about near-misses are more likely to choose a risky alternative over a safe alternative.*

We test this below in three experiments (labeled 2, 3, and 4), in which participants must decide whether or not to drive an unmanned Mars rover through a severe dust storm (risking catastrophic wheel damage). Experiment 2 tests Hypothesis 4. Experiment 3 explores the role of statistical risk, finding little evidence that Bayesian updating of probabilities accounts for the tendency of decision makers with near-miss information to make riskier choices. Experiment 4 explores the role of perceived risk and finds substantial support for the idea that exposure to near-misses decreases participants' perceived risk, making them more optimistic about success when choosing a risky alternative, and thus encouraging riskier choice. In Experiment 4, we also examine alternative explanations for the risky choices of our participants with near-miss information, such as the hindsight bias (Fischhoff and Beyth 1975), augmenting (Kelley 1972), and that exposure to prior near-misses suggests an inferred social norm for risk taking.

4.1. Experiment 2 Method: Materials, Participants, and Procedures

Participants were 21 NASA managers and defense contractors and 25 undergraduate students. They were asked to assume operational control of an unmanned Mars rover starting on Day 6 of an 11-day mission (on Days 1–5 the rover operated on automatic pilot). Each simulated "morning," participants were given a 95% accurate weather forecast and had to decide whether to drive for the day or stop and deploy wheel guards. In a severe storm, the chance of catastrophic wheel failure was 40%. Participants were told that it was desirable to drive the rover, all else being equal, because of the rover's limited battery life, which depleted at a constant rate whether the rover was driven or not. To reinforce this point, student participants started with a reward of \$20 and had \$5 deducted each time they stopped until reaching a minimum payment of \$5,[6] but if the rover suffered a catastrophic wheel failure, the participants also received just \$5. All participants faced a severe dust storm forecast for Day 6. Half the participants received a near-miss manipulation: They were told that the rover had been driven through three severe storms (during Days 1, 2, and 4 of the mission) before they assumed driving responsibility. The control group was told that weather was mild for Days 1–5 of the mission.[7]

After completing decisions (either reaching the destination or experiencing a catastrophic failure), participants answered questions (on a 7-point Likert scale) designed to measure their engagement with the task, such as "I tried as hard as I could" and their individual risk propensity (using the Judge et al. 1999 risk-aversion measure), which included items such as "I am a cautious person who generally avoids risk."

The NASA and contractor sample was 81% male, with an average managerial experience of 20.36 years (s.d. $= 13.77$ years). Thirteen of the NASA and contractor participants completed the experiment supervised by a researcher, whereas the other participants received the materials via e-mail. Students completed the experiment in a computer lab supervised by a researcher.

4.1.1. Analysis and Results. To check the near-miss manipulation, participants were asked (after all decisions were made) how many storms had occurred during the first five days of the mission. ANOVA showed that participants in the near-miss condition recalled significantly more storms (mean $= 2.83$ s.d. $= 0.48$) than did those in the no-near-miss condition (mean $= 0.43$, s.d. $= 0.84$; $F_{(1,45)} = 144.9$, $p < 0.001$), suggesting that our near-miss manipulation was successful. Scales were constructed for task engagement (Cronbach's $\alpha = 0.67$) and risk propensity ($\alpha = 0.83$) by taking the average of all scale items.

[6] This incentive structure is intended to simulate the pressures facing NASA (and firms more generally) to proceed with the projects, all else being equal.

[7] Screen shots of the experimental material are available in the online supplement to this paper. An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

Conditions did not differ significantly in terms of participants' risk propensity (near-miss mean $= 3.52$, s.d. $= 0.93$; control mean $= 3.87$, s.d. $= 1.09$; $F = 1.42$, $p = 0.24$) or their task engagement (near-miss mean $=$ 4.85, s.d. $= 0.99$; control mean $= 4.61$, s.d. $= 1.01$; $F =$ 0.71, $p = 0.40$).

Binary logistic regression tested whether near-miss information had an effect on Day 6 decisions, controlling for sample, task engagement, and risk propensity. The model showed a significant effect for being in the near-miss condition ($\beta = -3.51$, $\text{Exp}(\beta) = 0.03$, $p = 0.005$), but no significant effects for sample, risk propensity, or task engagement. Eighteen of the 24 participants (75%) in the near-miss condition drove on Day 6, whereas only 3 of the 23 participants (13%) in the control condition drove on Day 6, highly significant differences ($\chi^2_{(1)} = 18.2$, $p < 0.001$) that support Hypothesis 4.[8]

4.1.2. Discussion. Although the data supported Hypothesis 4, the explanation for the risky choice remains unexamined. Participants with exposure to near-misses essentially have two somewhat conflicting pieces of information. On one hand, they have base-rate information (40% probability that driving in a storm will lead to failure); on the other hand, they have case-specific information (driving through the past three storms, the rover was unharmed). One way of combining these pieces of information is to use the case information to update the probability of failure (in this case, revising it downward). If participants are updating the engineers' estimates of the probability of failure, the participants in the near-miss condition had perhaps lower ratings of the probability of wheel failure than the participants in the control condition. That is, they had recalculated a lower statistical risk, leading the near-miss participants to make more risky choices. Using the engineer's 40% failure estimate and assuming that the participant started with a prior distribution based on the maximum entropy, applying Bayes Theorem, the updated mean probability of failure is 20%.[9] Clearly, a full Bayesian calculation is beyond participants' abilities when completing the rover task, yet research has shown that people are capable of intuitive Bayesian analysis (Martignon and Krauss 2003, Peterson and Beach 1967). One explanation of the results is that past participants may have been revising probability information (i.e., statistical risk) downward to explain their more risky choice.

Hypothesis 5. *If people with near-miss information make riskier choices than people without near-miss information, those with near-miss information will also have revised probability estimates for failure that are lower than those of the participants without near-miss information.*

4.2. Experiment 3 Method: Materials, Participants, and Procedures

Participants were 71 students and university staff. The procedure was the same as in Experiment 2, but the materials were altered in two ways. First, participants were told that the engineers' estimate of the 40% chance of wheel damage when driven through a storm was "a robust estimate based on 30 experimental trials that perfectly simulated the operating conditions on Mars." Here, updated posterior probabilities based on the three near-miss events should approximate 37%—very close to the original 40% failure probability. Thus, if people are focusing on statistical risk (probabilities) and updating this in a Bayesian framework, we should see very little difference between the near-miss and control conditions on decisions to drive or stop. However, if they are not focusing on statistical risk, but rather some other mechanism is impelling risky choice, we should again see a significant difference between the near-miss and control conditions. The other change in materials was to ask participants, "What is your current belief about the rover's probability of failure? Please enter a probability between 0% and 100%." Half of the participants were asked this question before they made their decision for Day 6, and half were asked it after making their decision. Both groups made these estimates before knowing whether or not the rover failed if they chose to drive.

4.2.1. Analysis and Results. ANOVA showed that participants in the near-miss condition recalled significantly more storms (mean $= 2.38$, s.d. $= 1.68$) than did those in the no-near-miss condition (mean $= 1.93$, s.d. $= 1.38$ ($F_{(1,67)} = 23.7$, $p < 0.001$), suggesting that

[8] Early comments from colleagues suggested that participants with near-miss information may have felt compelled to choose the riskier drive alternative because they made different inferences about the base rate of storms on Mars. We changed the simulation so that all participants were told there had been three storms in the last 14 days on Mars (on Days 1, 2, and 4 *of* the mission for the near-miss participants and on Days 1, 2, and 4 *before* the mission for the control participants), and that storm occurrences were completely independent from one day to the next. We recruited 36 more participants (students and university staff) and again found identical support for Hypothesis 4 (details upon request).

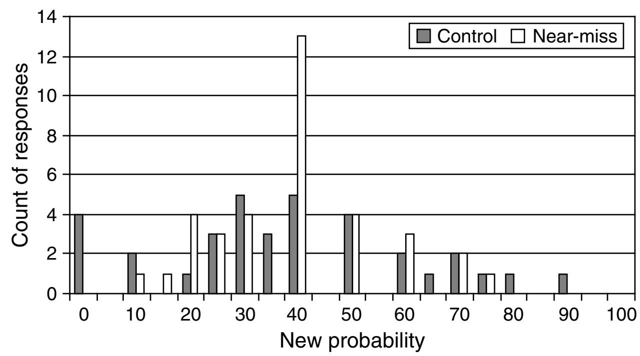
[9] Bayesian computation of probability distributions starts with a prior probability density function representing one's degree of belief about the different possible values for a parameter, and then updates this distribution based on observed data (Howard 1970). If nothing is known about a distribution except that it belongs to a certain class, then the maximum entropy distribution for that class is often assumed by default because the *least-biased* distribution that encodes certain given information is that which maximizes the "information entropy" (Howard 1970). The most noninformative prior given the constraint on the mean would yield a Beta distribution with parameters ($\alpha = 1.237$, $\beta = 1.855$). Updating this distribution with zero failures in three trials (driving through three storms successfully) yields a Beta distribution with parameters ($\alpha = 1.237$, $\beta = 4.855$) and a mean of 0.20.

our near-miss manipulation was successful. Conditions did not differ significantly in terms of participants' risk propensity or their task engagement.

A binary logistic regression was performed with Day 6 decision as the dependent variable; risk propensity and task engagement as the control variables; and condition, when probability was assessed, and the interaction of near-miss with when probability was assessed as the independent variables. This showed significant effects for near-miss information ($\beta = -2.19$, $\text{Exp}(\beta) = 0.12$, $p = 0.01$) and risk aversion ($\beta = -0.58$, $\text{Exp}(\beta) = 0.56$, $p = 0.03$), but no significant effect for task engagement, when probability was assessed, or the interaction of near-miss with when probability was assessed. Thus, Hypothesis 4 is again supported; 25 of 36 participants (69%) in the near-miss condition drove on Day 6, whereas only 13 of 35 participants (37%) in the control condition drove on Day 6, a significant difference ($\chi^2_{(1)} = 7.44$, $p < 0.001$). This also suggests that, contrary to Hypothesis 5, people with near-miss information are not using this information to update statistical risk; if they are updating probability information using Bayesian analysis, they should in this case evidence little differences in choice between the near-miss (where failure probability could be updated to 37%) and control (failure 40%) conditions. Given our design, Bayesian analysis does not offer a rational justification for people with near-miss information choosing the riskier alternative. The lack of a significant interaction suggests that near-miss information encourages people toward the risky choice, regardless of whether they are asked to assess probability information before or after making their decision.

ANOVA showed no significant differences across any conditions (near-miss versus no-near-miss; probability questions before the choice to drive versus after the choice to drive) on participants' current belief in the probability of wheel failure (near-miss/probability before mean = 39.75, s.d. = 17.13, near-miss/probability after mean = 38.75, s.d. = 14.66; control/probability before mean = 36.15, s.d. 15.31, control/probability after mean = 41.00, s.d. = 31.70). Figures 1 and 2 show the distribution of elicited probabilities by conditions and illustrate that participants in all conditions are just as likely to revise failure probabilities upward as well as downward, despite the fact that participants in the near-miss condition are significantly more likely to drive. These results, taken together, offer little support for the explanation that people with near-miss information make riskier choices because they use near-misses as data to recalculate the statistical risk (by revising downward the estimates of failure).

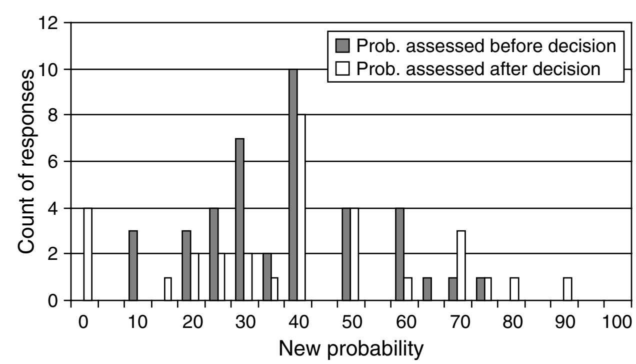
Figure 1 **Experiment 3 New Probabilities by Condition**



Note. No significant differences across any conditions (F near-miss versus $\text{control}_{(1,67)} = 0.02$, $p = 0.88$).

4.2.2. Discussion. Although we would argue that Bayesian analysis is an appropriate mechanism for revising risk probabilities (and indeed, Yi and Bier 1998 define a methodology based on copulas—i.e., multivariate cumulative distribution function with specific properties—for incorporating near-miss, or precursor, data into risk analyses), this updating mechanism does not provide a very descriptive explanation for our data. Our data seem more consistent with prior research showing people rely on vivid information and neglect to apply probabilistic methods to combine multiple pieces of information (Martignon and Krauss 2003, Doherty et al. 1996). For example, Huber et al. (1997) found that only 22% of subjects sought out probability information when evaluating several risky managerial decisions. Moreover, when people do update probability estimates, they anchor on initial estimates (Einhorn and Hogarth 1985) and therefore make overly conservative decisions (Peterson and Beach 1967). Our participants did not appear to focus on the statistical probability of failure, and revised probability estimates do not appear to explain their risky choices. We believe that near-miss information encourages riskier choices by decreasing participants' perceived risk.

Figure 2 **Experiment 3 New Probabilities by When Assessed**



Note. No significant differences across any conditions (F probability before versus $\text{after}_{(1,67)} = 0.16$, $p = 0.69$).

Table 4 Experiment 4: Descriptive Statistics for Dependent Variables

		Near-miss		Control			
Dependent variables	Question asked	Mean	Standard deviation	Mean	Standard deviation	$F_{(1, 113)}$	*p*-value
Perceived risk	How risky do you feel it is to drive today?	5.58	1.2	5.98	1.2	5.78	0.05
Lack of optimism	To what extent did you feel you would not make it if you drove today?	3.33	2.3	4.32	2.4	28.15	0.02
NASA values risk	To what extent do you believe that NASA management values risk taking?	3.40	1.8	3.57	1.8	4.39	0.24
Value of outcome	How valuable is it to arrive at the crater with as much battery life as possible?	6.15	1.2	5.65	1.4	7.17	0.05
Money motivation	How much do you agree with the statement: I wanted to get as much money as possible?	5.50	1.4	5.03	1.8	4.18	0.20
Risk in Days 1–5	How risky was it that the rover was driven on Days 1–5 of the mission?	4.75	1.4	2.68	1.4	112.54	<0.001
Bayes explanation	To what extent do you believe the engineer's estimate for the rover failure was too high?	3.37	2.0	3.2	2.0	0.09	0.87
Surprise/Kelley's augmenting	How surprised were you that the rover survived Days 1–5 of the mission?	4.85	1.6	3.19	1.6	65.56	<0.001

Near-miss events that exhibit little propensity toward failure (in the form of event cues that suggest failure is proximal) should decrease a decision maker's perception of the risk involved. Event propensity is tied to "causal scripts" (Kahneman and Varey 1990). Specifically, when an event appears to unfold over time toward a particular outcome, these temporal cues impart a sense of progress toward that focal outcome, causing people to believe that this is a more likely outcome (than when there is little event propensity). By the same logic, we would argue that if a near-miss event has little failure propensity, it should decrease participants' perception of the risk of failure happening in the future (even if the statistical probabilities or dispositions remain invariant—as seen above in Experiment 3).

In our studies, as with many near-misses, there is a statistical probability of failure that is moderately high (40%), yet there is little failure propensity—such as a causal script describing how a wheel starts to wobble, more and more, before correcting itself. Without event cues to support failure propensity, we argue that the prior near-misses serve to decrease participants' *perception* of the risk of failure, even if their statistical risk remains unchanged. This decrease in perceived risk for participants with near-miss information would make them more optimistic of their chance of success if they choose the risky alternative, making them more likely to choose this risky alternative, than people without near-miss information.

Hypothesis 6A. *Compared to people with no information about near-misses, people with exposure to near-misses will feel lower perceived risk.*

Hypothesis 6B. *Compared to people with no information about near-misses, people with exposure to near-misses will be more optimistic about their chance of success with the risky option.*

Hypothesis 6C. *Lower perceived risk and higher optimism can explain (mediate) why people with exposure to near-misses make riskier choices than people without near-miss information.*

4.3. Experiment 4 Method: Materials, Participants, and Procedures

Participants were 115 undergraduate and MBA students. The materials and procedure were the same as in Experiments 2 and 3, with the following exceptions. First, after participants made their Day 6 decision (drive or stop) and before they learned of their outcome (safe or failure), we asked questions to test Hypothesis 6. Table 4 details the questions presented to the participants to test mediating variables or alternative explanations: perceived risk, optimism in driving safely, a social norm toward risk, the value they placed on getting to their destination, their motivation for money, whether in hindsight driving in the first five days seemed risky, whether they should revise the statistical probability of failure, and their surprise at the rover's successful driving during the first 5 days.[10]

Second, we created another set of conditions (near-miss and control) where the probability of failure

[10] According to Kelley (1972), augmenting refers to a tendency to attach greater weight to a potential cause if the behavior occurs despite the presence of other inhibitory factors. This can cause initial surprise (that something occurred despite inhibitory factors), followed later by a reasoning that the cause of the behavior is stronger than originally assumed. In this case, there might be initial surprise that the rover made it safely (despite the inhibitory storm), followed by later reasoning that the cause of the safe passage was that the rover was stronger than originally assumed.

Table 5 Experiment 4: Pearson Correlations Between Dependent Variables

	Perceived risk	Lack of optimism	NASA values risk	Value of outcome	Money motivation	Risk in Days 1–5	Bayes explanation	Surprise
Perceived risk	1							
Lack of optimism	0.35**	1						
NASA values risk	−0.05	−0.13	1					
Value of outcome	−0.11	−0.22**	0.17	1				
Money motivation	−0.14	−0.36**	−0.01	0.15	1			
Risk in Days 1–5	−0.11	−0.14	0.02	0.12	0.02	1		
Bayes explanation	−0.13	−0.18*	0.13	0.18*	0.01	0.16	1	
Surprise	−0.01	0.03	0.11	0.02	0.08	0.67**	0.13	1

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

was 60% (rather than 40%) to test the sensitivity of our findings to different base rates of failure. Thus, Experiment 4 had four conditions: 40% failure near-miss versus control and 60% failure near-miss versus control.

4.3.1. Analysis and Results. As before, ANOVA showed that participants in the near-miss condition recalled significantly more storms (mean $= 3.02$, s.d. $=$ 0.83) than did those in the no-near-miss condition (mean $= 1.06$, s.d. $= 1.44$ ($F_{(1,114)} = 74.23$, $p < 0.001$), suggesting that our near-miss manipulation was successful, and there were no differences in participants' risk propensity across conditions. Participants in the 40% failure condition were more engaged (mean $= 5.36$, s.d. $= 0.90$) than those with a 60% failure (mean $= 4.83$, s.d. $= 1.01$) ($F_{(1,111)} = 7.17$, $p = 0.009$).

Binary logistic regression with Day 6 decision as the dependent variable; task engagement, risk propensity, and gender as the control variables; and near-miss, given probability of failure (40% versus 60%), and the interaction of near-miss and level of failure as the independent variables showed only a significant effect for near-miss information ($\beta = 2.01$, $\text{Exp}(\beta) =$ 7.49, $p = 0.006$). This means that regardless of the level of given failure probabilities (40% versus 60%), near-miss information has a main effect, making participants more likely to drive, supporting Hypothesis 4; 31 of the 52 participants (60%) in the near-miss condition drove on Day 6, whereas only 20 of 63 (32%) in the control condition drove on Day 6, a significant difference ($\chi^2_{(1)} = 8.97$, $p = 0.004$).[11] The lack of a significant interaction between near-miss and probability level of failure suggests participants in the 60% failure/near-miss condition drove no more or no less than participants in the 40% failure/near-miss condition.

Table 5 shows the correlation between all the potential mediator variables described in Table 4. Although there is some correlation between the variables, the only high correlation is between assessment of risk in the first five days of the mission and surprise at driving these days successfully ($r = 0.67$, $p < 0.001$).

To test whether perceived risk and optimism mediate the near-miss to risky behavior relationship we again use hierarchical regression (James and Brett 1984, Baron and Kenny 1986). To reduce any multicollinearity issues among the mediators, we assess whether the mediators are a probabilistic function of the independent variable (condition) with MANOVA. We use all the potential mediators in Table 4 (perceived risk, pessimism,[12] NASA norm for risk, value of outcome, money, risk in first five days, updating of engineers' estimates, and surprise) as the dependent variables; near-miss information, level of failure (40% versus 60%), and the interaction of near-miss and level of failure as the independent variables; and task engagement, risk propensity, and gender as covariates. The multivariate F is significant for near-miss condition ($F_{(8,101)} = 9.74$, $p < 0.001$) and also for the covariates task engagement ($F_{(8,101)} = 2.26$, $p = 0.03$) and risk propensity ($F_{(8,101)} = 2.75$, $p = 0.009$). As Table 4 shows, Univariate $F_{(1,113)}$ tests show that participants with near-miss information report lower levels of subjective risk, lower levels of pessimism, higher value for the outcome, higher assessments of risk in Days 1–5, and more surprise. The significantly lower ratings of perceived risk and pessimism for the near-miss condition versus the control participants support Hypotheses 6A and 6B, respectively. Given that there are significant differences between the near-miss and the control participants on all of these ratings, all of these variables are potential mediators.

[11] Although the interaction term was not significant, we did verify that near-miss information made participants more likely to drive within both failure probability conditions. For participants who read the probability of wheel failure was 40%: 14 of 20 (70%) in the near-miss condition drove versus 5 of 20 (25%) in the control condition ($\chi^2_{(1)} = 8.21$, $p < 0.01$). For those who read the probability of wheel failure was 60%: 17 of 32 (53%) in the near-miss condition drove versus 15 of 43 (35%) in the control condition ($\chi^2_{(1)} = 2.50$, $p < 0.05$, one-tailed).

[12] See Table 4—our question measured lack of optimism, so going forward we will refer to this as pessimism.

Step 2, the regression of the mediator variables on the dependent variable, tests which of these potential mediator variables, if any, actually influence the decision to drive or not. For this, we use a binary logistic regression with Day 6 decision as the dependent variable; task engagement, risk propensity and gender as the control variables; and perceived risk, pessimism, value for outcome, assessment of risk in first five days of mission, and surprise as independent variables. This showed a marginally significant effect on Day 6 driving decisions for the control variable risk propensity ($\beta = -0.60$, $\text{Exp}(\beta) = 0.55$, $p = 0.09$), as well as for two predictor variables, perceived risk ($\beta = 0.99$, $\text{Exp}(\beta) = 2.71$, $p < 0.01$) and pessimism ($\beta = 1.54$, $\text{Exp}(\beta) = 4.66$, $p < 0.001$). The R^2 for this equation is 0.62. Because the other predictor variables (value for outcome, assessment of risk in first five days, and surprise) do not share significant variance with the decision to drive or stop, it would be difficult to argue that they influence this decision. On the other hand, because perceived risk and pessimism do account for variance in the dependent variable, they could be mediators.

For Step 3, to test for full mediation we add near-miss condition to the above logistical regression as another independent variable. This regression again showed a significant effect for perceived risk ($\beta = 1.15$, $\text{Exp}(\beta) = 3.17$, $p < 0.01$) and pessimism ($\beta = 1.64$, $\text{Exp}(\beta) = 5.16$, $p < 0.001$), as well as continued marginal effects for our control variables task engagement ($\beta = -0.72$, $\text{Exp}(\beta) = 0.48$, $p = 0.07$) and risk propensity ($\beta = -0.73$, $\text{Exp}(\beta) = 0.48$, $p = 0.6$). The effect for near-miss condition is marginally significant ($\beta = 1.71$, $\text{Exp}(\beta) = 5.52$, $p = 0.07$). The R^2 for this equation is 0.63, so that the change in R^2 (0.01) is not significant. However, given that condition continued to be marginally significant in this full equation, the most conservative interpretation of our data is that perceived risk and pessimism largely, but perhaps not fully, mediate the relationship between exposure to near-misses and risky choice.

4.3.2. Discussion. Once again, participants with exposure to near-miss information made riskier choices than their control group counterparts, and this riskier choice was somewhat, though not fully, explained by the near-miss information decreasing participants' perceived risk and increasing their optimism about a favorable outcome. Although participants with exposure to near-misses also felt more surprised by the near-miss information (that the rover had made it through three prior storms), felt this driving was risky, and placed more value on completing their mission than the control participants, these feelings did not account for significant variance in participants' decisions to drive or stop. Moreover, initial estimates of wheel failure (40% versus 60%) had no influence on driving decisions; participants with near-miss information continued to drive even when the initial base rate for failure was 60%. That near-miss information decreases participants' perceived risk may be consistent with Kelley's augmenting principle. Lower perceived risk might arise from a belief in an unusually strong rover—a proposition that future research can test.

5. General Discussion

Near-misses are interpreted in a favorable light. In Study 1, participants evaluated managers whose decisions ended in a near-miss as equivalent to managers whose decisions ended in success, and more favorably than managers whose decisions ended in failure. This was true despite the facts that the focal manager made the same set of decisions and that the failure and near-miss outcomes differed only by chance (i.e., the chance alignment of the spacecraft to the sun at the time of the problem). Managers whose decisions resulted in near-misses were not held accountable, because the near-miss event itself was evaluated as a success rather than a failure. The near-miss outcome did surprise participants, suggesting that near-misses are not seen as deterministic successes. However, despite this surprise, near-miss outcomes do not create a sense of urgency, but rather appear to create a sense of complacency around a previously calculated level of statistical risk—what we have called a lowering of perceived risk.

Across a wide variety of decision makers (NASA managers and contractors, undergraduates, and MBA students), we found repeated evidence that near-miss information promotes riskier decisions (Experiments 2–4). As Experiment 3 shows, we found no evidence of Bayesian updating or recalculating of statistical risk. As Experiment 4 shows, we found strong support that near-misses decrease perceived risk. Specifically, participants with near-miss information chose to drive because they felt the situation was less risky and were more optimistic about their chances of making it through the storm. Although Experiment 4 tests many explanations for driving behavior (as detailed in Table 4), only perceived risk and pessimism accounted for variance in decisions to drive or stop. Thus, as with Experiment 1, results from Experiments 2–4 cumulatively suggest that with near-miss information, people feel safer about a previously calculated statistical risk. This would explain why near-misses create complacency rather than urgency, and thus present failed opportunities for managerial and organizational learning.

Although our study was not designed to test the existence of a dual process model (Windschitl and Wells 1998, Epstein 1990, Sloman 1996, Chaiken and

Trope 1999), our findings are consistent with this research. The dual process model posits that individuals have two general information-processing systems. Although there are several labels for these systems, one is generally rule-based (also called system 2), which operates according to formal rules of logic and evidence. The other is associative (system 1), which operates by principles of similarity so that the situational context has a direct and powerful influence on responses (Kahneman and Frederick 2005). We propose that our calculated statistical risk is the product of the rule-based system 2 processing, and our perceived risk is the product of the associative system 1 processing. Again we believe that both types of risk (and thus both information-processing systems) influence behavior, but that they may be differentially influenced by antecedent events. Specifically, near-misses appear to influence (here, decrease) perceived risk rather that statistical risk. This is consistent with the notion that situational context (e.g., near-misses) exerts a powerful influence on associative processing.

Scholars have speculated how these two processing systems interact to produce decisions, although most agree that associative system 1 processes often prevail over rule-based, system 2 processes (Kahneman and Frederick 2005). Our findings are consistent with this conjecture. If near-misses trigger associative processing focusing on perceived risk, whereas base-rate information supports rule-based processing of statistical risk, this might explain why associative processing and perceived risk dominate over rule-based processing and statistical risk in determining people's decisions to drive when near-miss information is available. Thus, our data suggests two different processing systems; that in the absence of an associative trigger, the rule-based system influences decisions to drive or stop (as in our control group), but that an associative trigger (near-misses) activates this system, which overweights decision making relative to the rule-based system.

5.1. Implications for Managers and Organizations

Managers often make "go" or "no go" decisions as projects move forward. Should a manufacturing line stop production when a defect is discovered? Should a subsidiary plant in a politically unstable country be closed after a demonstration? To answer such questions, managers are often counseled to produce a decision tree that lays out the options, probabilities, and value of each option, and to select the branch that gives the highest expected utility (Dawes 1988). We believe near-misses will muddy decision making because they separate (lower) perceived risk from statistical risk. Near-misses may trigger associative processing that focus attention on case-specific information rather than on the base-rate probabilities, and they may encourage people to move forward despite greater risk. Managers can be cautioned against using case-specific evidence when it is inconsistent with a priori determined decision models or hypotheses (Trope and Gaunt 1999). However, as we show, near-misses are hard to ignore and interpreting them as successes decreases perceived risk, and thus encourages riskier choices.[13]

When NASA experiences disasters such as the disintegration of *Columbia*, formal investigation boards are convened to identify the factors that contributed to the outcome and to help the organization to learn from its mistakes. As we suspect is the case in most organizations, prior near-misses did not command the same attention at NASA. On many shuttle missions before the *Columbia* disaster, foam debris detached from the shuttle, but luckily never hit a highly sensitive portion of the orbiter. Lacking an obvious failure, NASA managers interpreted the many near-misses as successes and accepted the detachment of foam as an ordinary occurrence. What was originally a cause for concern no longer raised alarms; deviance became normalized (Vaughan 1996, 1998). The influence of near-misses explains, in part, how an organization may become complacent to statistical risk, and thus why it fails to explore steps to mitigate that risk.

Another mechanism by which near-misses may spur unnecessary risk taking involves the risk behavior of the managers who are promoted within an organization. We found that a manager whose decisions ended in a success or near-miss was judged to be significantly more competent, more skilled in leadership and decision-making ability, and more deserving of promotion than a manager whose decisions ended in a failure. Hence, we conclude that managers whose decisions lead to near-misses are more likely to move up the corporate ladder than managers whose decisions end in unsuccessful outcomes. Coupled with the finding of our second set of studies—that people who have experienced near-misses choose significantly riskier alternatives than those who have not experienced near-misses—we further expect that those who are promoted may continue to choose more risky options than those who are not promoted. Assuming that the level of risk reflected in an organization's decisions is more heavily weighted by the risk choices of those at the high rather than the low levels of the organizations, then near-miss events will bias organizations toward riskier decisions over time. By the mechanism of managerial advancement, near-miss events might institutionalize risky decisions within an organization.

[13] This speaks to a danger of encouraging low-effort heuristic processing when it can provide a decision with a sufficient degree of confidence (Chen and Chaiken 1999).

5.2. What Can Be Done?

Understanding participants' behavior regarding near-misses is only one step toward attenuating how these events impede organizational learning. We have documented that near-misses are judged more favorably than failures, lower perceived risk, and increase comfort with risky choices. Possible actions to mitigate the influence of near-misses include (1) inducing counterfactual thinking, (2) heightening awareness of how perceptions of risk can change, and (3) making probability more salient. We discuss each of these in turn.

Prior research has shown that people with counterfactual mindsets will use more analytical decision-making processes (Kray and Galinsky 2003, Kray et al. 2006) and can be motivated to learn from past events (McMullen 1997, Markman and Tetlock 2000, Morris and Moore 2000). If, for example, people consciously note that they were quite close to a failure outcome and that they personally could have acted to avoid it (i.e., not blame circumstances), people may learn to alter future behaviors. However, all near-misses do not necessarily evoke counterfactual thoughts (Kahneman and Miller 1986), and not all counterfactual thoughts yield effect learning. We do believe that people can be primed with counterfactuals to think more critically of near-miss events (similar to Kray and Galinsky 2003, Kray et al. 2006, Galinsky et al. 2000, Roese 1994) and that counterfactual priming should promote more risk-averse decisions. In the context of near-misses, managers might engage in counterfactual thinking about near-misses by asking questions such as: Was this event a complete success? If not, why not? What factors, if changed, would have resulted in a failure, and how robust are these factors to change?

Other efforts might emphasize that managers' and organizations' perceptions of risk can change over time. Managers could be counseled to compare current choices to past ones to detect changing risk beliefs. Other activities to attenuate "risk creep" might focus attention on the merits of a caution. For example, reminding participants that NASA is a highly visible organization and as such must operate at a high-safety state would hopefully decrease the power of near-miss information to encourage risky choices.

Finally, increasing the salience of probability information may help participants focus on base rates rather than on near-miss evidence. Other interventions that decrease the salience of near-miss information might also attenuate risky choice. Future research could examine these mitigation techniques.

6. Conclusion

Our results show that people with near-miss information make riskier choices than those without this information, because the near-miss events lead them to perceive a lower level of risk regarding the decision situation. The interpretation of near-misses as evidence of a system's resiliency means that too many potential failures go underdiagnosed. However, in complex systems where many failure points exist, near-misses provide the opportunity to correct mistakes before they become catastrophes. The full learning value of near-misses will be realized only when they are separated from successes and examined to demonstrate not only system resilience, but also system vulnerability.

7. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

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Appendix. Case Materials

NASA's MIST Mission

The National Aeronautic and Space Administration (NASA) started a mission called Micro-Imaging Space Telescope (MIST) to study the formation and evolution of galaxies. The mission required a highly powerful, yet somewhat delicate, telescope that would be launched into space on a small explorer spacecraft. The mission was run by NASA Goddard under the direction of Chris, the MIST mission's project manager. The telescope was to be constructed as part of a subcontract by NASA JPL under the direction of Jamie, the instrument manager. You have been asked to evaluate the decisions Chris has made to accomplish this mission.

Because of the delicacy of the MIST telescope's lens, when the telescope is in the earth's atmosphere the lens is enclosed in a case filled with solid hydrogen. This cover is then carefully ejected once the telescope is in orbit so that the telescope can begin reading data. Although everyone at NASA Goddard and NASA JPL are proud of the development of this innovative telescope and lens protection system, relations between Goddard and JPL personnel have become somewhat strained because JPL, Goddard's sister center, was assigned a subordinate role in this mission. Chris, however, has been artful at managing this tension by ensuring that JPL's input is always solicited.

Late in the building process, Jamie was assigned to another project, and was replaced by Terry. This caused some delay in the building process. To recover this lost time, the telescope design team skipped a peer review of the telescope's electronics. Chris okayed this process.

Tracey, MIST's systems engineer, noticed that the design of the telescope's vents could cause a catastrophic problem. If the hydrogen was discharged at an extremely high rate (100 times the expected rate), it could exert a destabilizing force on the spacecraft. Tracy mentioned this risk to Chris, adding that the chance of this happening was highly unlikely. A redesign of the vent would require delaying the launch of the mission.

[*Chris decided to proceed with spacecraft launch as scheduled. The launch and deployment of the spacecraft was successful, and so far the MIST telescope has been sending back usable data for the past two months.*] (*Success Case*)

[*Shortly after launch, a digital error in the instrument's electronics ejected the cover too early. By chance, the spacecraft's random alignment to the sun caused all of the solid hydrogen to convert to a gas and vent at an extremely high rate. The force of the discharging hydrogen gas destabilized the spacecraft, and the mission was lost.*] (*Failure Case*)

[*Shortly after launch, a digital error in the instrument's electronics ejected the cover too early. By chance, because the spacecraft's random alignment to the sun shaded the instrument from the sun's rays, the solid hydrogen converted to a gas at a slow rate, producing no destabilizing force on the spacecraft. The MIST telescope has been sending back usable data for the past two months.*] (*Near-miss Case*)

Chris is now up for an annual review and you have been asked to evaluate the decision making.

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