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Moderation in all things, except when it comes to workplace safety: Accidents are most likely to occur under moderately hazardous work conditions

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Abstract

In this article, we argue that the relationship between workplace hazardousness and accidents is best characterized as an inverted-U, such that accidents are most likely to occur within moderately hazardous environments. Specifically, whereas highly hazardous work environments are strong situations in which there is a clear need for a high degree of safety behavior, the amount of safety behavior needed to minimize accidents within moderately hazardous environments is more ambiguous. Drawing on self-regulatory theories of work motivation, we argue that most individuals tend to exhibit a proportional response to hazardousness, such that moderately hazardous environments are met with a moderate degree of safety behavior. However, we demonstrate that proportional responses to hazardousness will ultimately yield an inverted-U relationship between hazardousness and accidents. Instead, a sharp, non-linear increase in safety behavior is needed to keep accidents at a low and constant level as hazardousness increases. We present four studies to test our hypotheses. Studies 1 and 2 used archival data to test our hypothesis of an inverted-U relationship between hazardousness and accidents in natural work settings. Studies 3 and 4 were experiments which replicated this finding, and more importantly, demonstrated that the inverted-U relationship between hazardousness and accidents was driven by a failure to sharply increase safety behavior in response to small increases in hazardousness. We conclude with a discussion of the implications of these results for the safety literature, particularly the need to educate workers regarding the pattern of safety behavior needed to fully offset environmental hazardousness.

1 INTRODUCTION

Many individuals are exposed to *hazardous* situations at work. We define hazardousness as the baseline likelihood of an accident, and conceptualize it as a function of the presence of stimuli with the potential to cause accidents (e.g., noxious chemicals, high voltage; Havinga et al., 2021). Likewise, *accidents* are unplanned incidents characterized by harm to people, property, or both (Beus et al., 2015, 2016). Whereas hazards provide the necessary conditions for an accident, whether an accident occurs is also influenced by worker behavior (Christian et al., 2009). For example, medical personnel wear protective equipment to prevent contracting diseases, truck drivers reduce speed to avoid crashes on icy roads, and machinery maintenance workers follow lock-out procedures to avoid injuries. Yet, these *safety behaviors*—actions that promote safety and minimize accidents (e.g., Beus et al., 2016; Burke et al., 2002; Griffin & Neal, 2000)—can be cumbersome and inefficient. Because individuals must allocate time and attention across multiple competing demands (e.g., productivity *and* safety), it is impractical to simply maximize safety behaviors across all work situations (Beus & Taylor, 2018).

Instead, individuals are more likely to adjust the degree to which they engage in safety behaviors according to the hazardousness of the situation (e.g., Beck et al., 2017; Feng et al., 2017). Within *highly* hazardous environments, individuals typically exhibit a high degree of safety behaviors, as these environments are characterized by rules, procedures, and physical barriers to ensure maximum safety behavior. In contrast, work environments with *relatively few* hazards require little (if any) effort to be allocated to safety behaviors. Yet, many work situations fall between these extremes. We argue that *moderately* hazardous environments are particularly challenging when it comes to matching safety behaviors to the demands of the situation.

Moderately hazardous environments leave room for interpretation regarding the level of safety behavior that is required to prevent accidents. For example, a truck driver is likely to recognize the need to reduce speed as winter conditions worsen. However, the *degree* to which speed must be reduced to prevent an accident may be uncertain. In this article, we demonstrate that keeping accidents at a low and constant level requires a *sharp*, *non-linear* increase in safety behaviors in response to relatively small increases in hazardousness. Yet, we expect that this is not obvious to many individuals. Instead, drawing on formal self-regulatory models (Ballard et al., 2016, 2018; Vancouver et al., 2010, 2014; Zhou et al., 2019), we expect the typical response to increased hazardousness is a relatively proportional increase in safety behavior. As a result, most individuals will not increase safety behaviors to the degree necessary within moderately hazardous environments. Thus, we predict an inverted-U relationship between hazardousness and accidents, meaning accidents are most likely to occur under moderately hazardous conditions.

We tested our predictions across four empirical studies. Studies 1 and 2 are archival field studies, and Studies 3 and 4 are experiments. These studies make a critical contribution to the workplace safety literature by demonstrating that balancing safety with competing work demands can produce an inverted-U relationship between hazardousness and accidents. Thus, whereas it is common for organizations to invest in safety training and messaging within highly hazardous environments (Grote, 2004, 2007), we identify a particular need to emphasize safety within moderately hazardous work environments as well.

2 | BALANCING SAFETY AND PRODUCTIVITY

For most workers, avoiding accidents is a constraint, rather than a primary objective. Although there are some work roles for which preventing accidents is the primary task (e.g., safety officer), for most occupations this is not the case. Instead, most individuals pursue primary work goals, yet must do so in a manner that minimizes accidents (Beus & Taylor, 2018). Thus, there is often a trade-off between safety and productivity. We argue that the hazardousness of the work environment is an important determinant of how this trade-off is managed.

We base our predictions on self-regulatory theories, which describe the processes involved as individuals allocate time, effort, and energy across multiple competing goals (e.g., Lord et al., 2010). With this theoretical backdrop, we conceptualize hazardousness as an input to a self-regulatory system. Our argument is that individuals monitor and regulate the *probability* of experiencing an accident. We focus on probability because accidents themselves are relatively rare events (Zohar, 2000). Yet, the *possibility* of an accident occurring is continuously present. The probability that an accident will occur is largely dependent on two broad factors: environmental hazards and safety behavior (e.g., Reason, 1990). Whereas hazards provide the potential for an accident, individuals can shift this probability through their safety behaviors (Christian et al., 2009). For example, although aviation is inherently hazardous, the probability of an accident is kept low via safety behaviors enacted by pilots (e.g., pre-flight checks), ground crew (e.g., maintenance), and air traffic controllers (e.g., maintaining minimum separation).

This argumentation is in line with Wilde's (1982, 1998) risk homeostasis theory, which is a specific instantiation of self-regulatory theory. It was originally developed to explain driving behavior but has been applied to other domains as well. The theory states that individuals possess internal referents for the maximum probability of an accident that they are willing to accept (which Wilde called "risk"). Wilde argued that individuals adjust behaviors to resolve discrepancies between this referent and the person's perceived probability that an accident will occur. In particular, he predicted that individuals adjust behaviors to keep the probability of an accident constant (and equal to the referent) across varying environmental conditions.

The central premise of risk homeostasis theory—that individuals adjust behaviors in response to changes in the perceived probability of an accident—is well supported (Trimpop, 1996). For example, Feng and colleagues found that construction workers were more likely to engage in safety behaviors (e.g., moving slowly on roofs) when safety measures (e.g., guardrails) were absent versus present (Feng & Wu, 2015; Feng et al., 2017). Likewise, Beck et al. (2017) found that individuals performing an air traffic control simulation reduced their use of unsafe shortcuts during trials that carried a higher (vs. lower) likelihood of a "near miss" incident. However, there is far less support for the idea that individuals adjust their behavior in a manner that *fully* compensates for changes in the perceived probability of an accident (Stetzer & Hofmann, 1996). That is, although there is evidence that individuals adjust their behaviors in response to hazardousness, Wilde's claims that individuals adjust their behaviors in a manner that keeps the probability of an accident to a constant and low level have been more contentious (e.g., Janssen & Tenkink, 1988; O'Neill & Williams, 1998).

Yet, it is not clear *why* individuals fail to fully offset environmental hazards. It may be the case that individuals do not possess the referents that Wilde (1982, 1998) described. We find this explanation to be unlikely. Accepting *some* probability of an accident is necessary for navigating day-to-day life. Every time a person rides in a car, takes a medication, or changes a light bulb they accept a chance of bodily harm. Although it may be difficult for an individual to articulate the precise likelihood of an accident that they are willing to accept (Slovic et al., 2004), the fact that individuals adjust their behavior in response to hazardousness indicates that individuals do indeed strive to avoid accidents. Furthermore, the mechanism that Wilde describes is well-supported by broader self-regulatory theories (e.g., Carver & Scheier, 1998; Lord & Levy, 1994; Powers, 1978), as well as empirical evidence (Lord et al., 2010; Neal et al., 2017).

To this end, we argue that individuals do indeed strive to regulate the probability of experiencing an accident, yet often fail to understand the pattern of safety behaviors needed to do so. We arrived at this argument using a formal approach to hypothesis development, meaning we state our predictions as mathematical formulas. Stating predictions formally avoids many of the ambiguities associated with verbal theories (Vancouver & Weinhardt, 2012). Additionally, this approach allows theories with common elements to be easily integrated (e.g., Steel & König, 2006; Vancouver et al., 2010). In the current manuscript, we incorporate elements of contemporary, formal theories of self-regulation (e.g., Vancouver et al., 2010) to explain how individuals adjust safety behaviors in response to environmental hazardousness. Yet stating predictions formally can also yield unanticipated insights (Adner et al., 2009). Chiefly, our formal model indicates that accidents are most likely to occur under *moderately* hazardous conditions. We describe this model is in detail in the following section.

3 | A FORMAL MODEL OF HAZARDOUSNESS, SAFETY BEHAVIOR, AND ACCIDENTS

3.1 | Effect of hazardousness and safety behaviors on the probability of an accident

We begin by describing the probability of an accident as a function of both environmental hazardousness and the time and energy spent engaging in safety behaviors:

$$A = H - H \times B \tag{1}$$

In Equation (1), "A" stands for the probability that an accident will occur within a given timeframe (e.g., one work shift), "H" stands for hazardousness, and "B" stands for safety behavior. $H = 0$ represents a complete absence of hazards. Setting $H = 0$ implies that no accidents will occur, regardless of safety behavior. In actuality, hazardousness only *approaches* zero; there is always some opportunity for an accident to occur, even if the likelihood is very low. Conversely, $H = 1$ represents maximum hazardousness, such that within a given timeframe an accident is guaranteed to occur, unless some action (i.e., safety behavior) is taken to prevent it. As was the case with the lower bound, it is more accurate to say that hazardousness *approaches* 1.0.

Examples of low hazardousness environments include offices and classrooms. Likewise, examples of highly hazardous work environments include logging, firefighting, and aviation. However, rather than being a purely static characteristic of an occupation or industry, hazardousness also varies across time and tasks. For instance, the hazardousness associated with work as a sailor is heavily dependent on the weather and sea conditions, just as police-work involves highly hazardous (e.g., arresting belligerent people) and less hazardous tasks (e.g., completing arrest paperwork). We argue that regardless of whether hazardousness is a relatively permanent feature of the job, or if hazardousness varies across time, individuals adjust their safety behaviors to match the demands of the situation.

As shown in Figure 1, Equation (1) describes a negative relationship between safety behaviors and the probability of an accident, which is in line with meta-analytic findings (Beus et al., 2015; Christian et al., 2009; Nahrgang et al., 2011). Yet, Equation (1) also reflects a variance restricted interaction (Cortina et al., 2019). Within highly hazardous environments, the probability that an accident will occur is free to vary, and this variance is accounted for by safety behavior. In contrast, within low-hazardousness environments, there is little potential for an accident, regardless of the safety behaviors enacted. For instance, donning a life preserver as one's ship goes through a storm may be the difference between life and death; wearing a life preserver while standing on the dock is far less likely to have a meaningful effect on safety outcomes. Finally, Equation (1) implies that as safety behaviors increase, the effect of hazardousness on

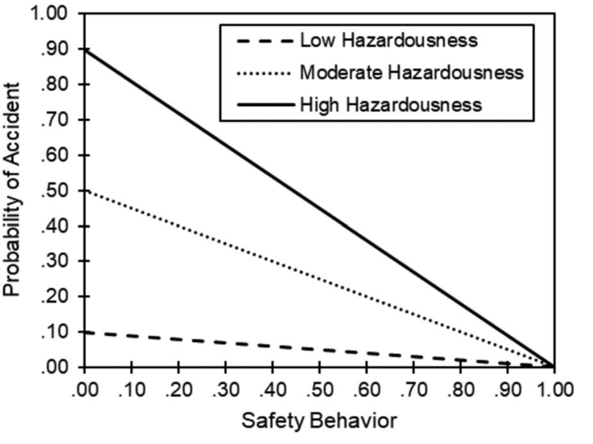


FIGURE 1 Theorized relationships between safety behavior, hazardousness, and accidents (Equation 1).

accidents is diminished. Conversely, when safety behaviors are minimized (B = 0), accidents are completely a function of the hazardousness of the environment[1].

3.2 | The need for a sharp, non-linear increase in safety behaviors

As noted above, keeping the probability of an accident to a constant level across varying levels of hazardousness may be easier said than done (Trimpop, 1996). Our model provides insight into why this might be the case. This is demonstrated by replacing the freely varying accident probability (A) variable in Equation (1) with a constant (see Equation 2).

$$R = H - H \times B \tag{2}$$

Here "R" is the referent for the maximum acceptable probability of an accident. Although there are probably various influences on these referents (e.g., severity of an accident), considering these sources is largely outside the scope of the current paper. Instead, we assume that individuals possess this referent, and that the value is greater than, yet close to, zero. This assumption is based on risk homeostasis theory (Wilde, 1982, 1998), the broader self-regulatory literature (e.g., Lord et al., 2010), and empirical research showing that individuals attempt to compensate for increased hazardousness (e.g., Beck et al., 2017).

Equation (2) allows us to answer the question: At each level of hazardousness (H), what level of safety behavior (B) is *needed* to hold the probability of an accident constant (R)? We do so by solving Equation (2) for safety behaviors (B). This is shown in Equation (3).

$$\mathrm{B} = \max\left[1 - \left(\frac{R}{H}\right), 0\right] \tag{3}$$

The "max" function prevents negative values for safety behavior (B) when the referent (R) is greater than hazardousness (H). In other words, when the environment is so unhazardous that the probability of an accident if no precautions are taken (B = 0) is *less than* an individual's maximum acceptable probability of an accident (R), this model does not yield negative values for safety behavior, which might be interpreted as deliberately unsafe behavior.

Equation (3) indicates that keeping the probability of an accident to a constant (and low) level requires a sharp, non-linear increase in safety behaviors in response to relatively small increases in hazardousness (see Figure 2). For example, Equation (3) suggests that a truck driver facing a small increase in hazardousness, such as a light snowfall,

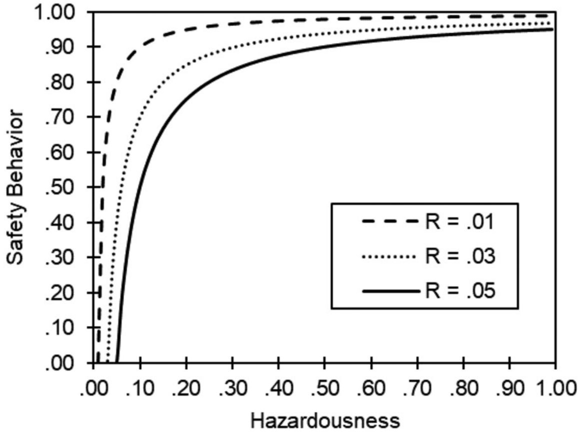


FIGURE 2 Relationship between hazardousness and safety behavior required to keep accidents at a low and constant level (Equation 3).

would need to sharply increase safety behaviors to maintain the same probability of an accident occurring as before the snow began to fall. This could include behaviors like dramatically reducing speed (i.e., shifting time allocation *away* from productivity and *toward* safety), narrowing attention (e.g., by turning off the radio), and increasing following distance (as well as other defensive driving techniques).

However, we believe individuals generally do not respond to increased environmental hazardousness in this manner. Instead, the typical response to increased hazardousness is likely to be a *proportional* increase in safety behaviors. This prediction is based on Vancouver and colleagues' formal model of self-regulation (Ballard et al., 2016, 2018; Vancouver et al., 2010, 2014; Zhou et al., 2019).

3.3 | A proportional response to environmental hazardousness

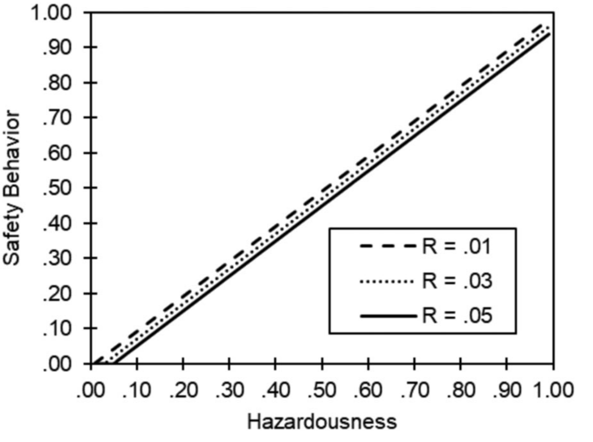
Vancouver et al.'s (2010) theory is presented as a computational model, meaning all predictions are expressed as mathematical formulas. This model has been updated several times, incorporating learning (Vancouver et al., 2014), avoidance-goals (Ballard et al., 2016), varying deadlines (Ballard et al., 2018), and leadership processes (Zhou et al., 2019). In each iteration, the models stipulate that the effort allocated to pursuing a goal is a function of goal progress. Specifically, the discrepancy between the goal and one's current state is conceptualized as the value of allocating effort toward a particular goal. Vancouver et al. explicitly model this as a *linear* relationship, meaning effort is *proportional* to the size of this discrepancy. In other words, larger discrepancies (i.e., the goal is far from being achieved) warrant a larger (and proportional) behavioral reaction relative to smaller discrepancies (i.e., the goal is close to being achieved). Across these papers, the model has been shown to provide a strong fit to empirical data.

The hazardousness of the work environment represents an input to a similar discrepancy.[2] In particular, drawing on Vancouver and colleagues' model, we expect effort allocated to safety behaviors to be proportional to the discrepancy between environmental hazardousness and the maximum likelihood of an accident that an individual is willing to accept. This prediction is stated formally in Equation (4):

$$\mathrm{B} = \max\,(H - R,\ 0) \tag{4}$$

As with Equation (3), here we use the "max" operator to prevent negative values for safety behavior. Furthermore, the referent (R) value can only shift the level of hazardousness at which individuals respond with increased safety behaviors; it does not affect the relationship between hazardousness and safety behavior. Instead, the critical aspect of Equation (4) is that it represents a proportional behavioral response to changes in environmental hazardousness (see Figure 3).

FIGURE 3 Proportional relationship between hazardousness and safety behavior (Equation 4).



At extreme low and high levels of hazardousness, this proportional response is likely to be effective for preventing accidents. Low hazardousness environments yield little motivation to engage in safety behaviors. This is reasonable because the likelihood of an accident is low, regardless of individual behavior (Reason, 1990). On the other hand, highly hazardous environments are strong situations in which the need to maximize safety behaviors is apparent (Meyer et al., 2010). These environments often contain signs, symbols, and other cues providing clear and consistent messaging regarding the need for safety behaviors. Also, hazardous tasks are often associated with rules and procedures which act as constraints on individual actions (Grote, 2004, 2007). Additionally, highly hazardous environments often contain physical constraints, such as guardrails, lock-out tags, and emergency shut-off mechanisms. Therefore, highly hazardous environments send a clear signal of the need for safety behaviors to be maximized.

Yet, many work environments fall between these two extremes. Whereas within highly hazardous environments the need for very high levels of safety behavior is clear, the amount of safety behavior required in moderately hazardous environments is more ambiguous. Moderately hazardous environments obviously require *some* investment in safety, yet individuals are unlikely to *maximize* time and effort allocated to safety behaviors in these environments, as doing so comes at the expense of productivity (Beus & Taylor, 2018). Thus, based on Vancouver and colleagues' model, we expect moderate hazardousness to be associated with moderate effort allocated to safety behavior. However, in the following section we demonstrate that this proportional response can be problematic within moderately hazardous environments.

3.4 | Insufficiency of proportional responses to moderately hazardousness environments

This can be seen by substituting Equation (4) into Equation (1). According to Equation (4), for environments in which hazardousness is less than the maximum likelihood of an accident that the person is willing to accept (i.e., where $H-R \leq 0$), safety behaviors are minimized ($B = 0$). Entering $B = 0$ into Equation (1) indicates that the probability of an accident is entirely a function of hazardousness in this scenario. On the other hand, Equation (4) stipulates that within environments in which hazardousness exceeds this referent ($H-R > 0$), the safety behavior term in Equation (1) can be substituted for $H-R$. After simplifying, this produces Equation (5):

$$A = H \times R + H - H^2 \tag{5}$$

Therefore, Equation (5) shows that proportional responses to hazardousness results in an inverted-U relationship between hazardousness and the probability of an accident (see Figure 4). When aggregated across time and

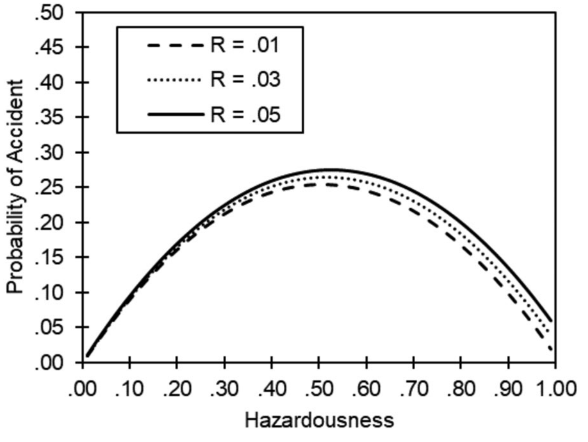


FIGURE 4 Theorized inverted-U relationship between hazardousness and accidents (Equation 5).

situations, this process will result in the highest number of accidents occurring within moderately hazardous situations. Thus, we hypothesize:

> *H1*: There is an inverted-U relationship between hazardousness and accidents, such that the highest number of accidents will be observed under moderately hazardous conditions.

Nonetheless, previous research has revealed person-level variance in responses to environmental hazards (Beck et al., 2017; Stetzer & Hofmann, 1996). Thus, whereas we expect the *typical* response to increased hazardousness to resemble the proportional response described by Equation (4), individuals are likely to vary in their degree of sensitivity to hazardousness. Some individual reactions to increased hazardousness may be closer to the non-linear response described by Equation (3), and as such, will prevent increased accidents under moderately hazardous conditions. This leads to our second hypothesis:

> *H2*: Behavioral sensitivity moderates the relationship between hazardousness and accidents. To the degree that individuals adjust safety behaviors in a manner that is proportional to hazardousness (Equation 4), they will experience an inverted-U relationship between hazardousness and accidents. To the degree that individuals adjust safety behaviors in a sharp, non-linear manner (Equation 3), they will experience a relatively low and constant level of accidents at all levels of hazardousness.

4 | OVERVIEW OF STUDIES

Studies 1 and 2 used archival field data to assess the relationship between hazardousness and accidents. In Study 1, we merged hazardous conditions data from the Occupational Information Network (O*Net) with injury data from the United States Bureau of Labor Statistics (BLS). Study 2 used maritime incident data reported by Transport Canada. These studies were used to test Hypothesis 1 within natural settings. Next, Studies 3 and 4 used experiments that allowed for within-person manipulations of hazardousness, as well as unobtrusive measurement of both safety behaviors and accidents. Thus, Studies 3 and 4 were used to test both Hypotheses 1 and 2, and did so within a controlled context, thereby holding potential confounds constant.

TABLE 1 Means, standard deviations, and correlations (study 1)

		Mean	SD	1	2	3
1.	Environmental hazardousness	32.46	26.09	1.00		
2.	Accidents	1695.94	5545.62	–.02	1.00	
3.	Number of employees	268.98	566.43	–.21***	.69***	1.00

Notes: $N = 571$ occupations. Number of employees is divided by 1000.
*** $p < .001$.

5 | STUDY 1

5.1 | Method

5.1.1 | Data sources and sample size

Data were downloaded from O*Net (www.onetonline.org) and the United States Bureau of Labor Statistics (BLS; www.bls.gov) on February 16, 2021. O*Net is an online database administered by the U.S. Department of Labor and the Employment Training Administration. It contains job analysis data for over 1000 occupations. The data are collected from job analysis experts and job incumbents. Environmental hazardousness data were retrieved from O*Net.

The BLS data used in this study were from the Injuries, Illnesses, and Fatalities program (IIF; www.bls.gov/iif) and the Occupational Employment Statistics program (OES; www.bls.gov/oes). Workplace injury data were retrieved from the IIF database. Number of employees per occupation was retrieved from the OES database to be used as a control variable. Both O*Net and the BLS use the Standard Occupational Classification (SOC) system to label occupations. Thus, data from O*Net were merged with data from BLS using SOC codes. We tested H1 in 571 occupations for which data were available in both sources.

5.1.2 | Measures

Environmental Hazardousness. We computed an environmental hazardousness variable as the average response to the following two questions: "How often does this job require exposure to hazardous conditions?" and "How often does this job require exposure to hazardous equipment?" O*Net respondents answered these questions on a scale from 1 (never) to 5 (every day), yet the O*Net database contains the percentage of individuals within the occupation that selected "5 – every day." Thus, the scores included in this study range from 0 to 100. The Spearman-Brown corrected reliability of this two-item composite was .85.

Accidents. We operationalizes accidents as cases in which an injury sustained at work resulted in the individual missing at least 1 day of work. These data are from 2019.

Number of Employees. The number of employees working in each occupation (in units of 1000 employees) was included as a control variable. This accounted for variance in injuries due to some occupations having larger numbers of employees than other occupations.

5.2 | Results

Table 1 contains means, standard deviations, and correlations for all Study 1 variables. It is noteworthy that environmental hazardousness was not significantly correlated with accidents. This is consistent with the hypothesized inverted-U relationship between these variables.

TABLE 2 Effect of hazardousness on accidents (study 1)

	b	SE	*t*	*p*	R^2	ΔR^2
Step 1:					.47	—
Intercept	−108.97	187.28	−.58	.561		
Number of employees	6.71	.30	22.45	<.001		
Step 2:					.49	.02
Intercept	−1109.86	294.30	−3.77	<.001		
Number of employees	6.99	.30	23.21	<.001		
Environmental hazardousness	28.53	6.54	4.36	<.001		
Step 3:					.50	.01
Intercept	−1801.07	351.50	−5.12	<.001		
Number of employees	7.03	.30	23.56	<.001		
Environmental hazardousness	100.49	21.46	4.68	<.001		
Environmental hazardousness^2	−.96	.27	−3.52	.001		

Notes: $N = 571$ occupations. Number of employees is divided by 1000.

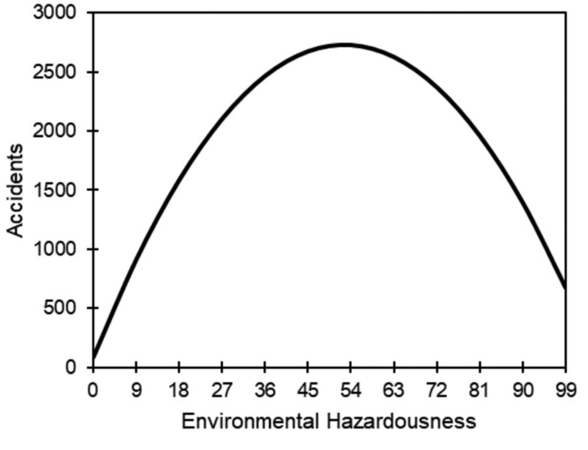


FIGURE 5 Curvilinear relationship between hazardousness and accidents (Study 1).

As shown in Step 2 of Table 2, the linear relationship between hazardousness and accidents was positive and significant when number of employees was included as a control variable. Nonetheless, as shown in Step 3, this linear relationship was qualified by the presence of a significant curvilinear effect. Furthermore, the plot of this curvilinear effect shows that there is an inverted-U relationship between hazardousness and accidents (Figure 5). Specifically, moderate levels of environmental hazardousness were associated with the highest levels of accidents. These results support H1.

Before moving on, a word of caution is warranted regarding the linear environmental hazardousness term in Step 3 of Table 2. Because the regression equation displayed in Step 3 contains a squared term, the linear term in this model represents the simple effect of hazardousness on accidents where hazardousness equals zero (Cohen et al., 2003). In this case, there is a positive relationship between hazardousness and accidents ($b = 100.49$, $SE = 21.46$, $p < .001$). If instead hazardousness is centered around 99 (such that −99 represents *low* hazardousness and 0 represents *high* hazardousness), the linear term in this equation becomes negative and significant ($b = -88.66$, $SE = 33.95$, $p = .009$), yet the nature of the curvilinear relationship does not change. Therefore, at high levels of hazardousness, *increased* hazardousness is associated with *fewer* accidents. This pattern of simple slopes is in line with H1.

5.3 | Discussion

Study 1 provides support for our first hypothesis; we observed an inverted-U relationship between environmental hazardousness and accidents, such that the highest levels of accidents occurred within moderately hazardous occupations. However, the fact that the data were aggregated to the occupation level of analysis limits our interpretations of these results. In particular, exposure to hazards can vary across time and situations, even within the same occupation. Therefore, although these data indicate that accidents are most likely to occur within occupations in which work environments are *on average* moderately hazardous, the results do not speak to the actual level of hazardousness present when accidents occurred. To this end, in Study 2 we use data collected at the incident level.

6 | STUDY 2

We used maritime incident data collected by the Canadian Transportation Safety Board (TSB) to provide an additional test of H1. Many of these reports include information about wind speed and sea conditions at the time of the incident, thereby providing an index of environmental hazardousness. In line with H1, we expected the relationship between hazardousness and accidents to follow an inverted-U pattern. When the seas are calm, there is little chance for a sailor to experience an accident. Likewise, when the seas are very rough, we expect most sailors to "batten down the hatches" and exhibit a very high degree of safety behavior. Yet, under moderately hazardous sea conditions, individuals may be less likely to take the necessary precautions, thereby leading to the highest likelihood of an accident.

6.1 | Method

6.1.1 | Data sources and sample size

Data were downloaded from the TSB (http://www.bst-tsb.gc.ca/eng/stats/marine/data-6.html) on September 12, 2022. This database contained 44,741 Canadian maritime incidents that occurred between January 1975 and August 2022. However, in many records, information about wind speed and sea conditions (i.e., environmental hazardousness) was missing.[3] Nonetheless, there were 17,472 (39%) incidents for which these data were included.

6.1.2 | Measures

Environmental hazardousness. We operationalized environmental hazardousness as the composite of two indicators: *wind speed* (knots) and *sea conditions*. High winds can cause instability, increasing the chance of falls (including overboard). Likewise, sea conditions refer to the size of the waves and swells, which also affect vessel stability. Sea conditions were recorded using an ordinal scale with 10 levels ranging from "0: Calm – 0 meters" to "9: Phenomenal—over 14 meters."[4] We formed a composite of these two indicators by converting each indicator to z-scores to put them on the same scale. We averaged each z-score and added a constant, such that a score of zero represents an incident during which wind speed was zero knots and the sea was calm. The Spearman-Brown corrected reliability ($k = 2$) of this composite was .91.

Accidents. We used the number of serious injuries sustained during each incident to operationalize accidents.[5] This variable is similar to the dependent variable used in Study 1 (i.e., injuries requiring time away from work). However, in the current data this variable was extremely skewed ($skew = 6.81$, $SE = .02$, $z = 367.48$, $p < .001$), with the modal number being zero (95.52% of observations). This extreme departure from normality precluded the use of ordinary least squares regression (Cohen et al., 2003). Therefore, we dichotomized this variable such that zero serious injuries was coded 0, and any value greater than zero was coded 1.

TABLE 3 Means, standard deviations, and correlations (Study 2)

		Mean	SD	1	2	3	4
1.	Environmental hazardousness	.86	.82	1.00			
2.	Accidents	.04	.21	.01	1.00		
3.	Number of people on board	23.59	129.46	–.03***	.04***	1.00	
4.	Vessel size	–.03	.91	–.07***	.06***	.23***	1.00

Notes: $N = 17{,}472$ observations.
***$p < .001$.

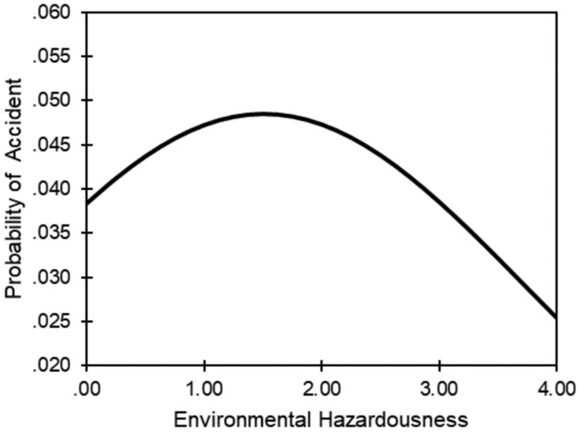


FIGURE 6 Curvilinear relationship between hazardousness and the probability of an accident (Study 2).

Number of people on board. We included the number of people on board each vessel when the incident occurred as a control variable. This is similar to controlling for the number of people in each occupation in Study 1. That is, the greater the number of people on board, the greater the possibility of one of them experiencing a serious injury.

Vessel size. Larger vessels are likely to be more stable than smaller vessels, which may mitigate the hazardousness of wind and sea conditions for larger vessels.[6] Therefore, we included vessel size as a control variable. Specifically, we computed a composite of the vessel's length, width, and tonnage. This was done by first converting each of these variables to z-scores and then computing the mean. Alpha reliability of this composite was .93.

6.2 | Results

Means, standard deviations, and correlations for all Study 2 variables are presented in Table 3. As was the case in Study 1, there was no significant bivariate correlation between hazardousness and accidents. Next, using logistic regression, we regressed accidents on the squared hazardousness variable, controlling for the linear term, number of people on board, and vessel size. These results are summarized in Table 4, and the probability of an accident across levels of environmental hazards is plotted in Figure 6.[7] In line with H1, there was an inverted-U relationship between hazardousness and accidents, such that accidents were most likely to occur under moderately hazardous conditions. Whereas there was a 3.8% chance of a serious injury occurring when hazards were at their lowest point, this increased to 4.9% at the apex of the curve shown in Figure 6 (i.e., a 26% increase). Therefore, despite the relatively small effect sizes in Table 4, there was nonetheless a meaningful impact of hazardousness on the likelihood that an individual sailor would experience an accident. Furthermore, given the serious nature of on-the-job injuries, even small effects warrant attention.

TABLE 4 Effect of hazardousness on the probability of an accident (Study 2)

	b	SE	Wald χ^2	*p*	R^2	ΔR^2
Step 1:					.011	—
Intercept	−3.09	.04	6774.64	<.001		
Number of people on board	.0004	.0002	6.12	.013		
Vessel size	.24	.03	47.76	<.001		
Step 2:					.011	.000
Intercept	−3.14	.05	3355.04	<.001		
Number of people on board	.0004	.0002	6.25	.012		
Vessel size	.24	.03	48.69	<.001		
Environmental hazardousness	.05	.04	1.56	.212		
Step 3:					.012	.001
Intercept	−3.22	.07	2389.26	<.001		
Number of people on board	.0004	.0002	5.97	.015		
Vessel size	.24	.03	50.42	<.001		
Environmental hazardousness	.33	.13	6.77	.009		
Environmental hazardousness^2	−.11	.05	5.11	.024		

Notes: $N = 17{,}472$ observations. R^2 values are Cox and Snell (1989) generalized coefficient of determination, rescaled so the maximum value is 1.0 (Nagelkerke, 1991).

Finally, the positive linear term in Table 4 indicates that at low levels (hazardousness = 0), increases in hazardousness were associated with an increased probability of an accident. Yet, beyond a certain point, increases in hazardousness were associated with a decreased probability of an accident. Specifically, for hazardousness levels above 3.70, the linear relationship between hazardousness and the probability of an accident is negative ($b_{3.70} = -.47$, $SE = .24$, $p = .050$). As was the case in Study 1, this pattern of simple slopes supports H1.

6.3 | Discussion

Study 2 substantiates H1. That is, compared to Study 1, Study 2 provides a more direct test of H1 by demonstrating that accidents were most likely to occur at times when conditions were moderately hazardous. Nonetheless, neither Study 1 nor Study 2 included individual safety behavior data. This is an important limitation, as we argue that the inverted-U relationship between hazardousness and accidents is a function of safety behaviors. To this end, Study 3 used an experiment to test H1 and H2. Doing so allowed us to manipulate hazardousness, as well as directly and unobtrusively observe safety behaviors and accidents. This allowed us to demonstrate that the inverted-U relationship between hazardousness and accidents can be explained by insufficient behavioral sensitivity to hazards.

7 | STUDY 3

The data used for Study 3 were originally collected to assess the effects of construal level (e.g., Liberman & Trope, 2008) on behavioral reactions to varying levels of environmental hazardousness. As such, participants were randomly assigned to either a low- or high-level construal condition. However, the initial hypotheses were not supported, and instead we determined that these data could be used to test our current hypotheses. As detailed in the SOM, the construal level manipulation did not affect any substantive conclusions drawn in the current manuscript. Thus, here we present the results collapsed across construal level conditions. Finally, we collected several variables that are not included in the analyses reported below. The SOM contains a complete list of these variables, along with analyses demonstrating that inclusion of these variables does not change the conclusions presented in this manuscript.

7.1 | Method

Study 3 received clearance from the University of Waterloo Office of Research Ethics (#20445; "Warehouse Manager Study").

7.1.1 | Participants

Ninety-five undergraduate psychology students from a Canadian university participated in exchange for course credit and an opportunity to earn a cash reward (described below). Three participants experienced technical difficulties during the experiment; data from these participants were not analyzed. The final sample of 92 participants was 63% female and had a mean age of 20.11 ($SD = 1.88$) years. Thirty-two percent of the participants were Asian, 27% were White, and the remaining participants indicated identifying with other races.

7.1.2 | Procedure

Participants completed a work simulation over the course of a 90-minute laboratory study. The study used a within-subjects design, such that all participants were exposed to all levels of the hazardousness manipulation. This manipulation is described in greater detail below. Between one and five participants completed the study during each experimental session, yet there was no interaction among participants.

After arriving and giving informed consent, participants completed the demographics questionnaire. Next, participants completed the training portion of the study, which involved viewing several slides explaining the experimental task. Training was broken into four sections, with each section focused on a particular aspect of the task. This was done to ensure that all participants understood how to perform the task before beginning the experimental trials. Participants answered knowledge check questions and completed practice trials to ensure they understood the information covered during training. The training lasted approximately 45 min, yet participants were free to move at their own pace.

Following training, participants performed 10 experimental trials, each of which lasted 90 s. Prior to each trial, participants were told what the level of hazardousness would be. Following each trial, participants were given feedback about their performance, including how many accidents had occurred. This sequence was repeated for all 10 trials. Following the final trial, participants were paid the money they had earned and were debriefed and dismissed.

Experimental Task. Participants performed a computerized work simulation adapted from Omodei and Wearing's (1995) Networked Fire Chief (NFC) program. Although NFC was developed as a forest fire fighting simulation, it can be used to model nearly any process that unfolds over time. In the current study the NFC program was used to create a warehouse work simulation. The objective of the task was to move boxes from a temporary storage area to one of several shelves within the 90 s time limit. This was done by using the computer mouse to move a forklift to pick up a box, move the forklift to the desired location, and unload the box. A labeled screenshot is shown in Figure 7. Participants were paid $.10 for each box that was moved. During each trial there were 10 boxes, meaning participants could earn a maximum of $1.00 per trial and $10.00 across the experiment. On average, participants earned $4.14 (SD = 1.03, Min = .70, Max = 6.00).

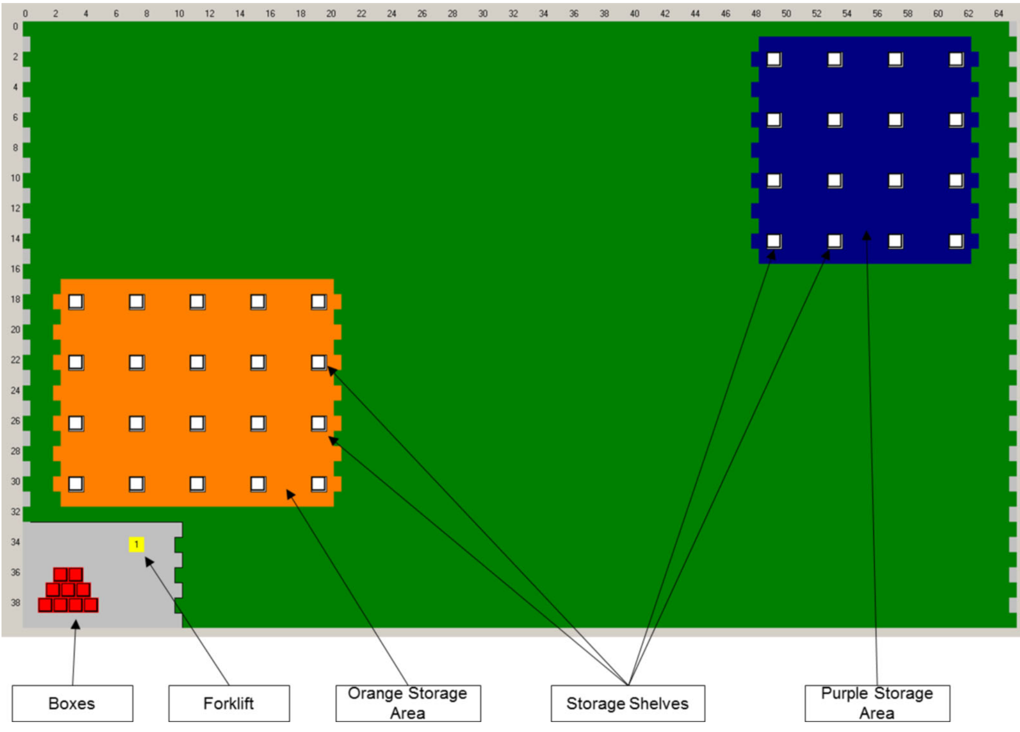


FIGURE 7 Labeled screenshot of experimental task (Study 3).

As shown in Figure 7, there were two areas that contained storage shelves: the orange storage area and the purple storage area. During the training trials it was explained to participants that they could move boxes to shelves in either area. It was made clear that because the orange storage area was closer than the purple storage area, moving boxes to the orange storage area was faster than moving boxes to the purple storage area. However, moving boxes to the orange storage area was potentially hazardous. Specifically, participants were told that some of the storage shelves in the orange storage area would be unstable. Any box that was placed on an unstable shelf would cause an accident, which in turn would result in no money earned for that box, as well as a $.20 loss. Losses were subtracted from the total money participants earned.

Unstable shelves appeared exactly the same as stable shelves, meaning participants could not identify the unstable shelves during the trial. Participants did not know if they had placed a box on an unstable shelf until feedback was delivered at the end of the trial. However, during the trial, participants were aware of the percentage of shelves in the orange storage area that were unstable. That is, participants knew *how many* shelves were unstable during a trial, but they did not know *which* shelves were unstable. On the other hand, all of the storage shelves in the purple storage area were stable. Thus, participants could avoid accidents by only moving boxes to shelves in the purple storage area, yet this was slower, meaning fewer boxes could be moved. Following each trial participants were given feedback regarding the number of boxes moved to the orange storage area, the number of boxes moved to the purple storage area, and the number of boxes moved to unstable storage shelves (i.e., accidents).

Environmental Hazardousness Manipulation. We manipulated hazardousness via the percentage of unstable shelves in the orange storage area. This was a within-subjects manipulation; all participants were exposed to low (10%), moderate (30%), and high (50%) hazardousness trials. These values were chosen based on the results of a pilot study ($N = 23$) in which the percentage of unstable shelves varied from 0% to 90% in 10% increments. As expected, when there was 0% chance of an accident, nearly all pilot participants moved all 10 boxes to the orange storage space ($Mean = 9.91$, $SD = .29$, $Min = 9$, $Max = 10$). Yet, at 10% chance of an accident, there was considerable variance in the number of boxes moved to the orange storage space (*Mean* = 6.30, *SD* = 3.31, *Min* = 0, *Max* = 10). Therefore, 10% was chosen as the value for low hazardousness in the focal study. The mean number of boxes moved to the orange location decreased with each increment in hazardousness up to 50%, yet at 50% there was still variance in this behavior (*Mean* = .74, *SD* = 1.51, *Min* = 0, *Max* = 6). However, beyond 50% the mean number of boxes moved to the orange storage area remained low (<1) and the variance in this behavior decreased at each incremental increase in hazardousness. Thus, 50% was chosen as the value for high hazardousness. Finally, because 30% is the midpoint between 10% and 50%, 30% was chosen as the value for moderate environmental hazardousness.

During the first trial of the focal study, the percentage of unstable shelves was 30% for all participants. The remaining nine trials were split evenly between 10%, 30%, and 50% unstable shelves, with the order of presentation counterbalanced. Therefore, participants performed three trials in which 10% of the shelves in the orange storage area were unstable, four trials in which 30% of the shelves in the orange storage area were unstable, and three trials in which 50% of the shelves in the orange storage area were unstable. As stated above, the unstable shelves could not be distinguished from the stable shelves during the trial. Furthermore, the specific location of the unstable shelves varied from trial to trial, meaning participants could not learn the location of the unstable shelves from experience. Similar to actual work tasks, accidents were a function of both behavior and luck (Campbell et al., 1993; Vancouver et al., 2016). Whether or not a box placed in the orange storage area resulted in an accident was driven by chance. Yet, participants could avoid accidents entirely by moving boxes to the purple storage area.

7.1.3 | Measures

Safety Behaviors. The proportion of boxes moved to the purple storage area during a trial was used to operationalize safety behavior.

Accidents. The number of collapses due to moving boxes to unstable shelves was used to operationalize accidents.

Sensitivity to environmental hazardousness. Testing H2 requires operationalizing participants' patterns of behavior in response to varying levels of hazards. That is, we needed to capture between-person variance in the within-person relationship between hazardousness and safety behaviors. To do so, we computed sensitivity to environmental hazardousness (hereafter, "sensitivity") using Equation (6):

$$S = (\bar{B}_{mod} - \bar{B}_{low}) - (\bar{B}_{high} - \bar{B}_{mod}) \quad (6)$$

In this equation "S" refers to sensitivity, and "B" refers to safety behaviors. Specifically, sensitivity was defined as a function of the average level of safety behaviors in which each individual engaged during the low (k = 3), moderate (k = 4), and high (k = 3) hazardousness trials. This equation captures the change in behavior between low and moderate levels of hazardousness, as well as between high and moderate levels. A perfectly positive and linear relationship between hazardousness and safety behaviors produces a sensitivity value of 0, as the change in behavior between low and moderate hazardousness is equal to the change in behavior between moderate and high hazardousness. Conversely, high sensitivity, in which the change in safety behavior from low-to-moderate hazardousness is *larger* than the change in safety behavior from moderate-to-high hazardousness, produces positive values. Likewise, low sensitivity, in which the change in safety behavior from low-to-moderate hazardousness is *smaller* than the change in safety behavior from moderate-to-high hazardousness, produces negative values. Therefore, this variable represents between-person variance in sensitivity.

7.1.4 | Analysis plan

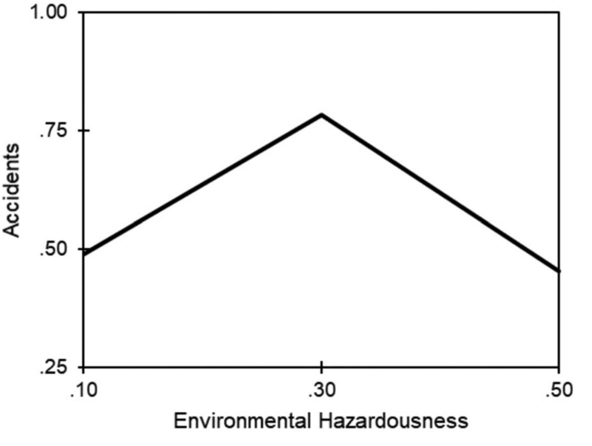
We used multilevel modeling (MLM) to account for the nesting of observations within individuals (Raudenbush & Bryk, 2002). The hazardousness condition was coded as a continuous variable with values of .10 (low), .30 (moderate), and

TABLE 5 Means, standard deviations, and correlations (Study 3)

		Mean	SD	1	2	3	4
1.	Environmental hazardousness	.30	.16	1.00			
2.	Accidents	.60	.82	–.02	1.00		
3.	Safety behavior	.50	.40	.69***	–.45***	1.00	
4.	Sensitivity	.10	.39	.00	–.22***	.26***	1.00

Notes: $N = 920$ observations nested within 92 individuals. ***$p < .001$.

FIGURE 8 Curvilinear relationship between hazardousness and accidents (Study 3).



.50 (high).[8] We tested H1 by regressing accidents on the squared hazardousness variable, controlling for the linear term. We tested H2 by first computing the sensitivity variable described in the previous section. Next, we used the sensitivity variable as a moderator of the relationship between hazardousness and accidents. Doing so demonstrates that engaging in the pattern of behavior depicted in Equation 3 keeps accidents at a low and constant level, whereas deviations from this pattern yields an inverted-U relationship between hazardousness and accidents.

7.2 | Results

7.2.1 | Descriptive statistics

Means, standard deviations, and correlations for all Study 3 variables are presented in Table 5. As with Studies 1 and 2, there was no significant bivariate correlation between hazardousness and accidents. This is consistent with an inverted-U relationship between these variables. We provide more direct tests of our hypotheses below.

7.2.2 | H1: Inverted-U Relationship Between Hazardousness and Accidents

There was a significant curvilinear relationship between hazardousness and accidents (Table 6, Step 2). This relationship is plotted in Figure 8. In support of H1, there was an inverted-U relationship between hazardousness and accidents. Specifically, there were significantly more accidents during the moderate hazardousness trials ($M = .78$, $SD = .88$) relative to both the low ($M = .49$, $SD = .56$, $t(182) = 4.13$, $SE = .07$, $d = .61$, $p < .001$) and the high hazardousness trials ($M = .45$, $SD = .91$, $t(182) = 4.64$, $SE = .07$, $d = .68$, $p < .001$).

TABLE 6 Effect of hazardousness and sensitivity to hazardousness on accidents (Study 3)

	γ	SE	t	p	R^2	ΔR^2
Step 1:					.00	—
Intercept	.62	.06	9.83	<.001		
Environmental hazardousness	–.09	.16	–.56	.576		
Step 2:					.04	.03
Intercept	.11	.10	1.05	.297		
Environmental hazardousness	4.58	.77	5.97	<.001		
Environmental hazardousness^2	–7.79	1.25	–6.22	<.001		
Step 3:					.12	.09
Intercept	.00	.10	.01	.995		
Environmental hazardousness	5.95	.77	7.68	<.001		
Environmental hazardousness^2	–10.00	1.26	–7.92	<.001		
Sensitivity	1.04	.26	4.04	<.001		
Environmental hazardousness × Sensitivity	–13.14	1.93	–6.80	<.001		
Environmental hazardousness^2 × Sensitivity	21.31	3.15	6.76	<.001		

Notes: $N = 920$ observations nested within 92 individuals.

As was the case in Studies 1 and 2, caution is warranted before interpreting the linear term in Table 6. Specifically, this term provides the linear slope between hazardousness and accidents where hazardousness equals zero (Cohen et al., 2003). However, there were no trials during which hazardousness was equal to zero. To address this issue, we re-ran this analysis three times, each time centering hazardousness around one of the three possible values (.10, .30., .50). In line with H1, the linear relationship between hazardousness and accidents was positive ($\gamma = 3.03$, $SE = .53$, $p < .001$), null ($\gamma = -.09$, $SE = .16$, $p = .567$), and negative ($\gamma = -3.21$, $SE = .53$, $p < .001$) at low (.10), moderate (.30), and high (.50) levels of hazardousness, respectively.

7.2.3 | H2: Safety Behavior Accounts for the Relationship Between Hazardousness and Accidents

To test H2, we began by plotting the relationship between hazardousness and safety behaviors for each participant. As shown in Figure 9, there was a great deal of variability in the degree to which individuals adjusted their safety behaviors. Although some participants exhibited a pattern similar to the sharp increase in safety behaviors described in Equation 3 (e.g., #51), other participants demonstrated a more linear response to hazards (e.g., #1) similar to the relationship described in Equation 4. Furthermore, other participants were relatively insensitive to hazardousness, only increasing safety behaviors during highly hazardous trials (e.g., #87). To this end, we computed the sensitivity variable described in the Method section to operationalize this variance. This variable provides a numeric summary of each individual's within-person relationship between hazardousness and safety behavior.

In line with H2, sensitivity moderated the curvilinear relationship between hazardousness and accidents (Table 6, Step 3). As shown in Figure 10, the inverted-U relationship between hazardousness and accidents was most pronounced among individuals who were relatively insensitive to hazards. Likewise, individuals who increased safety behavior in a manner that was more-or-less proportional to hazardousness (i.e., moderately sensitive) also experienced the highest number of accidents during the moderately hazardous trials. Lastly, individuals who were highly sensitive to hazards, such that they increased safety behavior sharply (a la Equation 3), experienced a relatively low

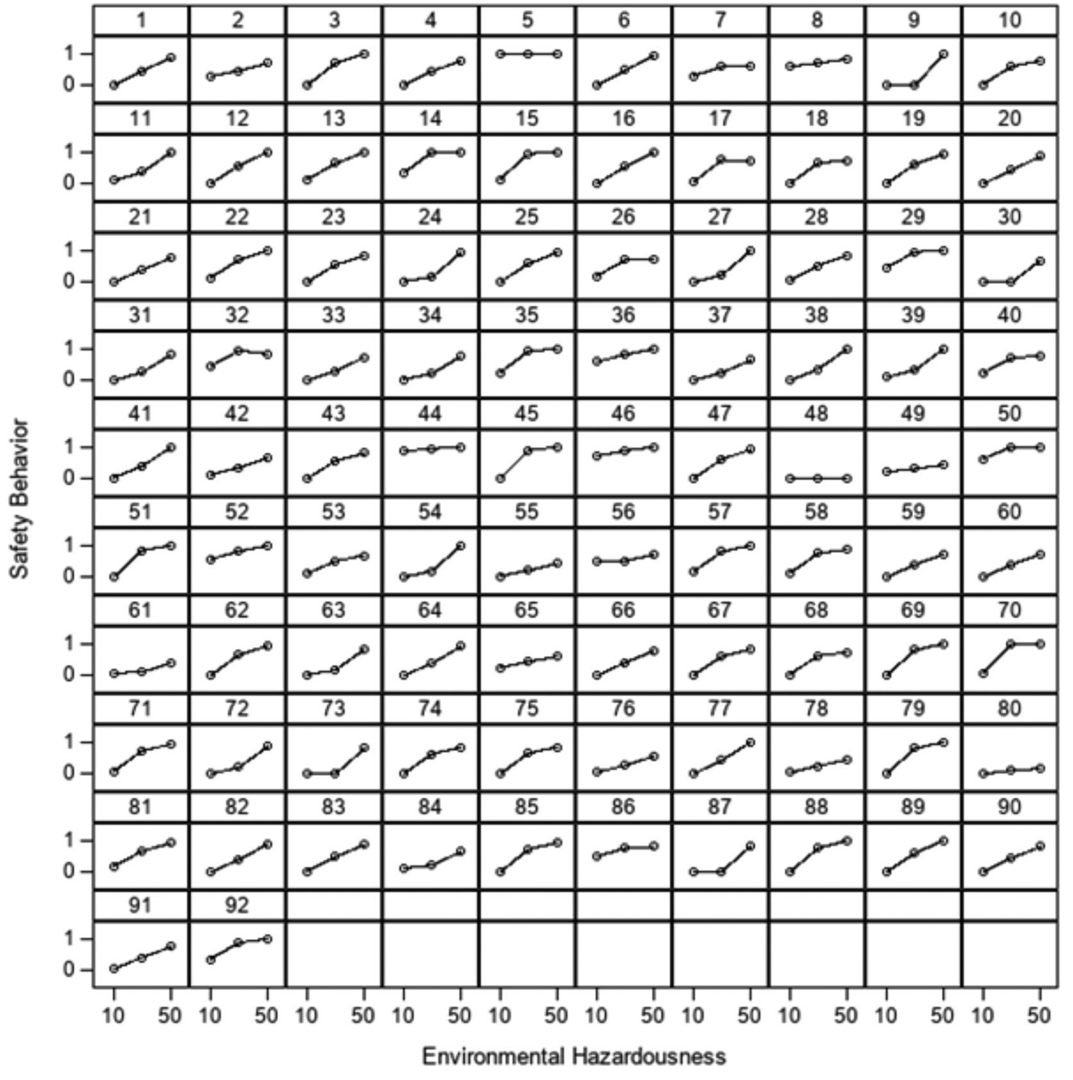


FIGURE 9 Trellis plot of the relationship between hazardousness and safety behavior for all participants (Study 3).

and constant number of accidents across all levels of hazardousness. Thus, these results support H2; the inverted-U relationship between hazardousness and accidents was driven by a failure to enact enough safety behaviors under moderately hazardous conditions.

7.2.4 | Auxiliary analyses

Recall that the first trial was moderately hazardous for all participants (hazardousness was counterbalanced during the remaining nine trials). Thus, it is possible that the inverted-U relationship between hazardousness and accidents was affected by this design feature; specifically, participants may have caused more accidents during the first trial due to lack of experience with the task. We addressed this issue in two ways. First, we included trial (as well as the squared trial term) as a control variable. These terms were nonsignificant in both the test of H1 and H2, and controlling for

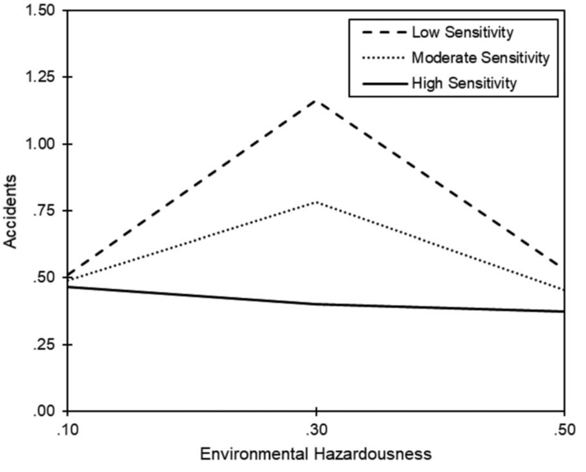


FIGURE 10 Sensitivity moderates the relationship between hazardousness and accidents (Study 3).

trial had no meaningful effects on the test of either hypothesis. Second, we recomputed the hypothesis tests excluding observations from the first trial. Again, this change had no meaningful influence on the results. Therefore, the pattern of results is not an artifact of this feature of the design. These results are available in the SOM.

7.3 | Discussion

Study 3 provides additional evidence for the inverted-U relationship between hazardousness and accidents. More importantly, Study 3 demonstrated that this relationship occurs because of a failure to adjust safety behaviors to the degree necessary under moderately hazardous conditions. However, the data reported in this study were originally collected for a different purpose. There were only three levels of hazardousness (low, moderate, and high), meaning the coarseness of this manipulation limited our ability to observe the relationship described in Equation (3). We addressed this limitation directly in Study 4.

8 | STUDY 4

8.1 | Method

Study 4 received clearance from the University of Waterloo Office of Research Ethics (#41698; “Foundry Manager Study”).

8.1.1 | Participants

We recruited 92 participants from Amazon’s Mechanical Turk (MTurk). Participants resided in the United States and had previously completed at least 100 MTurk assignments with a 95% acceptance rate. We included six comprehension check items to ensure participants understood the task instructions. Thirteen participants who did not answer all six items correctly were excluded. An additional three participants did not complete the experiment. The final sample of 76 individuals was 41% female, 68% White, and had an average age of 37.25 (SD = 9.82) years. Forty-five (59%) of the participants reported having a bachelor’s degree or higher. Sixty-seven (88%) participants were employed, and

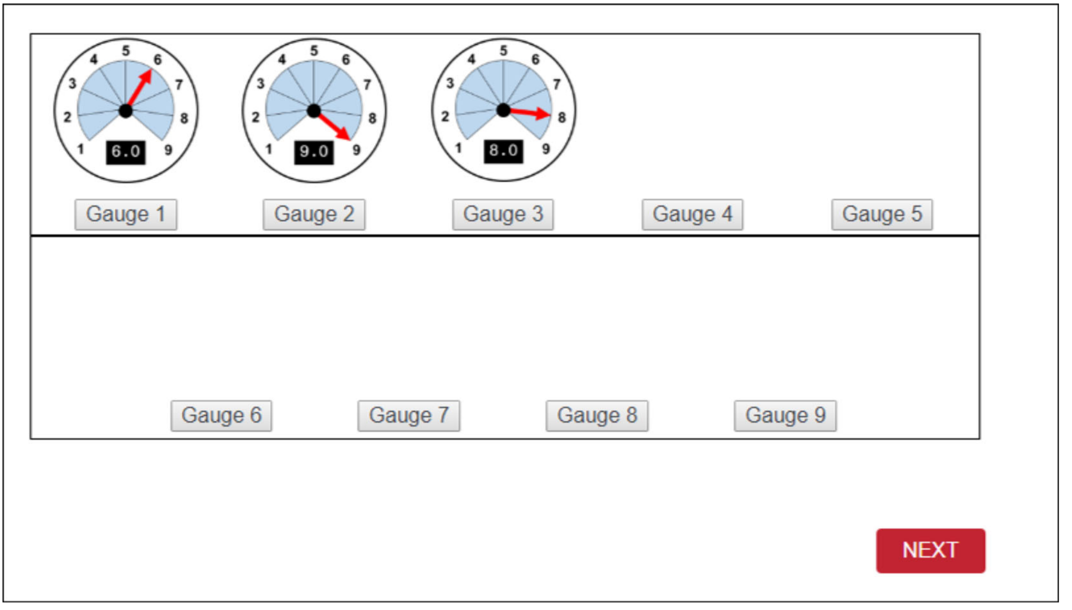


FIGURE 11 Screenshot of experimental task (Study 4).

these individuals worked an average of 34.07 (SD = 12.57) hours per week with a median annual income between $40,000 and $49,000.

8.1.2 | Procedure

Participants completed an online work simulation administered via Qualtrics. As with Study 3, this study used a within-subjects design, such that participants were exposed to all levels of the hazardousness manipulation. The study required approximately 20 minutes to complete, but participants could move at their own pace. Participants were paid $2.00 USD for completing the study. Additionally, participants had the opportunity to earn up to $4.00 USD in bonus pay for meeting specific speed (i.e., productivity) and accuracy (i.e., safety) goals. More detail regarding these goals and incentives is provided in the following section.

After providing informed consent, participants were shown several slides introducing them to the task. These slides also contained information about the goals and incentives. Following these introductory slides, participants performed a single practice trial. Next, participants performed nine experimental trials, each of which corresponded to a different level of hazardousness. Similar to Study 3, participants were told the hazardousness level prior to each trial, and participants were given feedback following each trial. After the final trial, participants completed a measure of risk propensity[9] and provided demographic information. Participants were then debriefed and paid via MTurk.

Experimental Task, Goals, and Incentives. The experimental task was developed for this study. Participants were told that they would act as a manager of a foundry, and that their job was to monitor several gauges displaying the temperature of liquid metal. A screenshot of the task is shown in Figure 11. At the onset of each trial all temperature gauges were hidden. Participants were told that the more gauges they checked during a trial, the more *accurate* their temperature readings would be. The accuracy of temperature readings determined the amount of *damage* that would be done to the finished product. However, there was a 1.5 s delay between the time when the button was clicked and when the temperature was displayed, meaning the more gauges that were checked, the more time that was required to complete the trial. Therefore, there was a trade-off between productivity and safety.

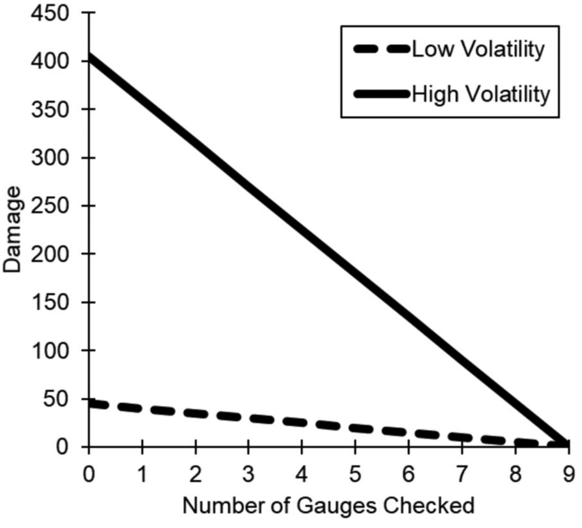


FIGURE 12 Plot of relationship between safety behavior (number of gauges check), hazardousness (volatility), and accidents (damage) shown to participants (Study 4).

Participants were assigned goals corresponding to both speed and safety. The speed goal was to spend no more than an average of 15 s per trial. Participants would not lose any bonus pay as long as they completed the trials with an average time of 15 s or less. However, for each second beyond 15, $0.10 was subtracted from their bonus pay. This time goal was set such that it was possible, yet challenging, to complete the experiment without losing any bonus pay. On average, participants spent 12.56 (SD = 3.57) seconds per trial.

The safety goal was to ensure that the average amount of damage across the nine experimental trials did not exceed 45. Specifically, damage scores could range between 0 and 405 and was computed using a version of Equation (1), with weights adjusted for this specific context. This is shown in Equation (7):

$$D = 45 * H - 5 * H * G \tag{7}$$

Here "D" represents damage, "H" represents hazards, and "G" represents the number of gauges checked. For each unit of damage beyond 45, $0.25 was deducted from the bonus payment.

In total, participants had the opportunity to earn up to $4.00 USD in bonus pay. If a participant's performance resulted in more than $4.00 being lost, the participant would not receive any bonus pay ($0.00), yet this participant did not owe any money. That is, all participants received the $2.00 base pay, regardless of their performance. On average participants earned $2.01 (*SD* = 1.81, *Min* = $.00, *Max* = $4.00) in bonus pay.

Environmental Hazardousness Manipulation. We manipulated hazardousness by varying the "volatility" of the metal used each trial. Participants were told that foundries use a variety of metals to make their products, and that some metals are more volatile than others. Prior to each trial, participants were told what the volatility would be. Volatility values ranged from one to nine, in one-point increments. Across the nine trials, participants were exposed to each level of volatility one time. The order of presentation was randomized.

Participants were told that the higher the volatility of the metal, the stronger the influence that checking gauges would have on damage. To this end, participants were shown Figure 12, in which the relationship between their behavior (i.e., gauges checked), volatility, and damage is depicted (i.e., Equation 7). Additionally, participants were shown several slides explaining how to interpret this figure. Participants were told that whereas checking very few gauges when volatility is high would result in a great deal of damage, very little damage would be done when volatility is low, regardless of the number of gauges checked. It was also made clear that this figure only displayed the lowest and highest levels of volatility, and that the relationship between gauges checked and damage when volatility took on other values (i.e., 2, 3, 4, etc.), lies between the lines shown in the figure. Finally, it was explained that the figure indicated that when volatility was at its lowest level, damage would not exceed 45 (the goal level) even if no gauges were checked.

TABLE 7 Means, standard deviations, and correlations (Study 4)

		Mean	SD	1	2	3	4
1.	Environmental hazardousness	5.00	2.58	1.00			
2.	Accidents	64.12	61.55	.09*	1.00		
3.	Safety behavior	5.56	2.76	.61***	−.59***	1.00	
4.	Sensitivity	.38	.86	.00	−.15***	.09*	1.00

Notes: $N = 684$ observations nested within 76 individuals. $^{*}p < .05$, $^{***}p < .001$.

Likewise, participants were told that the figure indicated that when volatility was at its highest level, a minimum of eight gauges needed to be checked to limit damage to 45.

Measures

Safety Behaviors. The number of gauges checked during each trial was used to operationalize safety behavior.

Accidents. The amount of damage done was used to operationalize accidents.

Sensitivity to Environmental Hazardousness. We operationalized sensitivity similarly to Study 3. However, because there were nine levels of hazardousness in the current study, we used regression to capture each participant's relationship between hazardousness and safety behavior. That is, we computed two slopes between hazardousness and safety behavior for each participant. First, we regressed safety behavior on hazardousness, where hazardousness was restricted to the low-to-moderate range (between 1 and 5). Second, we repeated this process, restricting hazardousness to the moderate-to-high range (between 5 and 9).

Sensitivity was computed as the difference between these two slopes (Equation 8):

$$S = b_{haz=1\ to\ haz=5} - b_{haz=5\ to\ haz=9} \tag{8}$$

As was the case in Study 3, a proportional response to hazardousness produces a sensitivity value of 0, in line with Equation (4). Conversely, participants with positive sensitivity values exhibited a sharp increase in safety behavior in response to increased hazardousness in the low-to-moderate range. This pattern is in line with Equation (3). Lastly, participants with negative sensitivity values were less responsive to changes in hazardousness in the low-to-moderate range, relative to changes in hazardousness in the moderate-to-high range. Thus, as was the case in Study 3, the sensitivity variable captures between-person variance in the within-person relationship between hazardousness and safety behavior.

8.1.3 | Analysis plan

Data were analyzed in the same manner as Study 3. As with Study 3, controlling for trial number (and the squared trial term) had no influence on the results. Thus, do we not include trial as a control variable in the analyses reported below.

8.2 | Results

8.2.1 | Descriptive statistics

Means, standard deviations, and correlations are presented in Table 7. Unlike Studies 1–3, there was a small positive correlation between hazardousness and accidents ($r = .09$, $p = .013$). Nonetheless, this is not in and of itself incompatible with an inverted-U relationship. Therefore, we provide direct tests of the hypotheses below.

TABLE 8 Effect of hazardousness and sensitivity to hazardousness on accidents (Study 4)

	γ	SE	t	p	R^2	ΔR^2
Step 1:					.01	—
Intercept	52.82	5.91	8.94	<.001		
Environmental hazardousness	2.26	.72	3.13	.002		
Step 2:					.04	.03
Intercept	17.61	8.14	2.16	.034		
Environmental hazardousness	21.46	3.17	6.77	<.001		
Environmental hazardousness^2	−1.92	.31	−6.21	<.001		
Step 3:					.09	.05
Intercept	5.84	8.71	.67	.505		
Environmental hazardousness	28.78	3.39	8.49	<.001		
Environmental hazardousness^2	−2.57	.33	−7.78	<.001		
Sensitivity	30.96	9.30	3.33	.001		
Environmental hazardousness × Sensitivity	−19.23	3.62	−5.31	<.001		
Environmental hazardousness^2 × Sensitivity	1.71	.35	4.85	<.001		

Notes: $N = 684$ observations nested within 76 individuals.

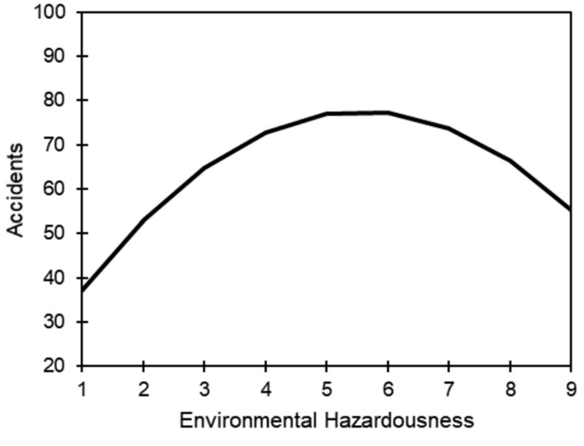


FIGURE 13 Curvilinear relationship between hazardousness and accidents (Study 4).

8.2.2 | H1: Inverted-U Relationship Between Hazardousness and Accidents

As anticipated, there was an inverted-U relationship between hazardousness and accidents. The regression weights for this analysis are contained in Step 2 of Table 8, and this relationship is plotted in Figure 13. Again, caution is warranted when interpreting the linear term in Table 8. Whereas this term represents the linear slope between hazardousness and accidents where hazardousness equals zero, in the current data the lowest hazardousness value was 1.0. Thus, we re-ran this analysis nine times, centering hazardousness around each possible value. These analyses indicate that for hazardousness values less than or equal to 5.0, the linear slope between hazardousness and accidents was positive and significant ($\gamma_{haz=5} = 2.26$, $SE = .70$, $p = .001$). Likewise, for hazardousness values greater than or equal to 7.0, the linear slope between hazardousness and accidents was negative and significant ($\gamma_{haz=7} = -5.42$, $SE = 1.42$, $p < .001$). This pattern of slopes is in line with an inverted-U relationship. Thus, H1 was supported.

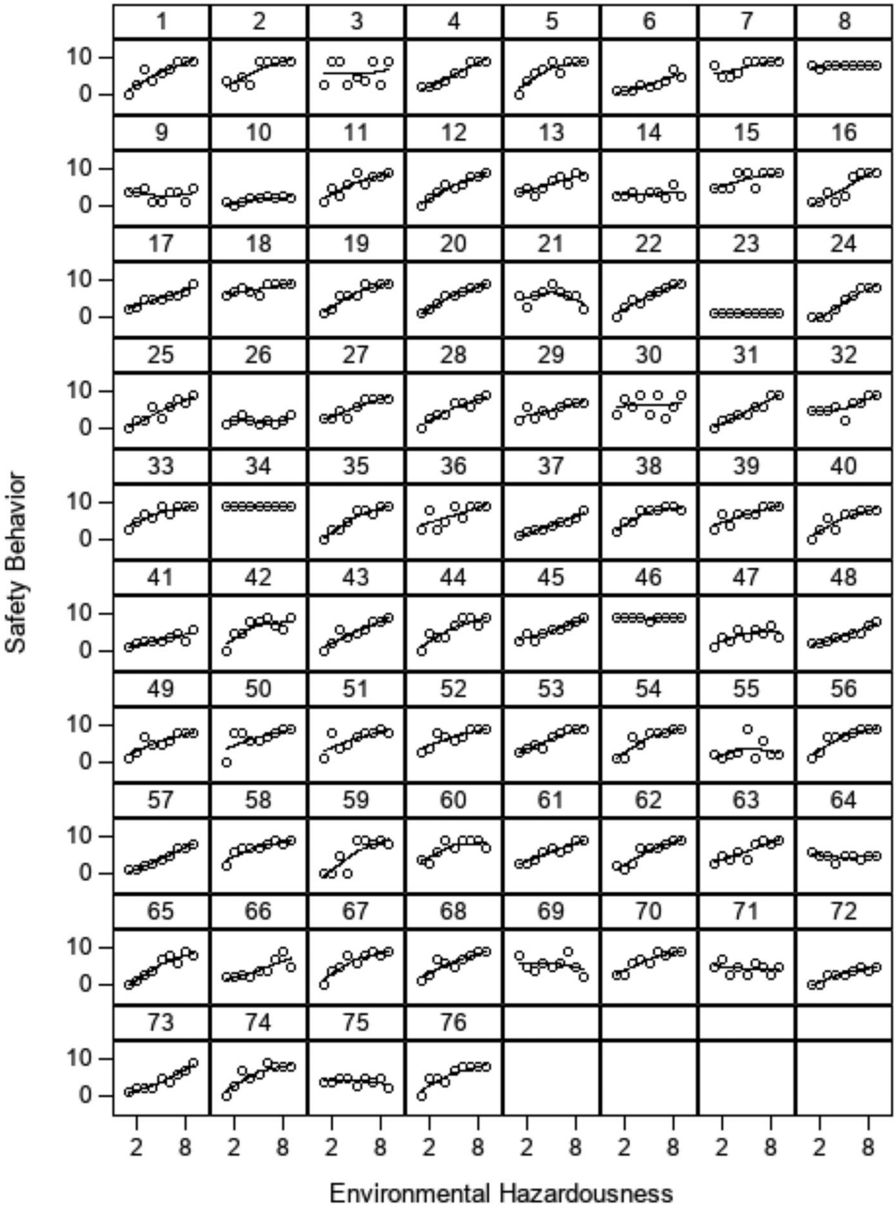


FIGURE 14 Trellis plot of the relationship between hazardousness and safety behavior for all participants (Study 4).

8.2.3 | H2: Safety Behavior Accounts for the Relationship Between Hazardousness and Accidents

As with Study 3, there was a great deal of variability in individual responses to hazardousness. Figure 14 contains a plot of this relationship for each participant. Some participants' responses were consistent with Equation 3; that is, they sharply increased safety behaviors in response to small increases in hazardousness (e.g., #5). Other participants increased safety behaviors in a more linear (i.e., proportional) manner, consistent with Equation (4) (e.g., #57).[10] Thus, we computed the sensitivity variable to operationalize this variance.

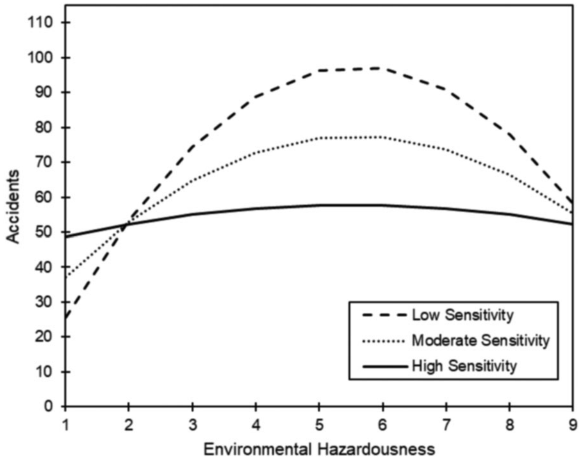


FIGURE 15 Sensitivity moderates the relationship between hazardousness and accidents (Study 4).

Next, we included sensitivity as a moderator of the relationship between hazardousness and accidents (Table 8, Step 3). As shown in Figure 15, individuals who were highly sensitive to hazardousness maintained a relatively consistent level of accidents. Conversely, individuals who deviated from the pattern shown in Equation (3) experienced the most accidents during the moderately hazardous trials. Therefore, H2 was supported.

8.3 | Discussion

The current study replicated the results from Study 3 using a task that was explicitly designed to test our hypotheses. In particular, relative to Study 3, Study 4 used a finer-grained hazardousness manipulation, containing nine levels instead of only three. Additionally, Study 4 represents a particularly strong test of our hypotheses. For one, the referent level for accidents was explicit; participants needed to regulate their behavior in accordance with the referent to maximize their financial rewards. Furthermore, participants were shown Figure 12, meaning they knew exactly how their behaviors would interact with environmental hazardousness to determine accidents. Despite this level of transparency, most participants did not increase their safety behaviors sufficiently to fully offset the environmental hazards. This lends credibility to our contention that the sharp increase in safety behaviors needed to prevent accidents under moderately hazardous conditions is not obvious or intuitive to most people.

9 | GENERAL DISCUSSION

9.1 | Summary of findings

This research demonstrates that accidents are most likely to occur within moderately hazardous environments. Studies 1 and 2 demonstrate this effect in actual work settings using large archival datasets, and Studies 3 and 4 replicate this effect using controlled experimental studies. Furthermore, Studies 3 and 4 show that the inverted-U relationship between hazardousness and accidents is driven by behavioral reactions to hazards. Most individuals increased safety behaviors in response to increased hazardousness, yet there was considerable variance in the *pattern* of behavioral responses. On average, individuals increased safety behaviors in a manner that was more-or-less proportional to the degree of hazardousness. This behavioral pattern resulted in an inverted-U relationship between hazardousness and accidents. Yet, some individuals increased safety behaviors sharply in response to small increases in hazardousness, similar to the pattern shown in Equation (3). These individuals maintained a low and constant level of accidents, regardless of the hazardousness present in the environment.

9.2 | Theoretical implications

9.2.1 | The relationship between hazardousness and accidents

Meta-analyses of the safety literature describe a small positive correlation between hazardousness and accidents (Christian et al., 2009; Nahrgang et al., 2011). If interpreted on its own, this implies accidents become more likely as environment hazardousness increases. Yet, the current research provides evidence for an inverted-U relationship, such that accidents are most likely to occur within moderately hazardousness environments. Although it may seem that our results run contrary to the meta-analytic evidence, this is not necessarily the case. Indeed, a positive correlation between two variables is not in and of itself incompatible with an inverted-U relationship (Pierce & Aguinis, 2013). Instead, the current research indicates that meta-analytic estimates of the relationship between hazardousness and accidents are incomplete. Although there may indeed be a small positive relationship between hazardousness and accidents, the current research indicates that this relationship is qualified by the presence of a curvilinear effect.

9.2.2 | Failure to fully compensate for environmental hazards

Drawing on risk homeostasis theory (Wilde, 1982, 1998), we argued that individuals would increase safety behavior in response to increased environmental hazardousness. Indeed, in Studies 3 and 4 nearly all participants did so. This is in line with previous research in the work domain (Beck et al., 2017; Feng & Wu, 2015; Feng et al., 2017), as well as numerous studies designed to test risk homeostasis theory (Trimpop, 1996). Yet, like previous research (e.g., Stetzer & Hofmann, 1996), we also found that most study participants failed to *fully* compensate for environmental hazardousness. That is, most participants did not adjust safety behaviors to the degree necessary to keep the probability of an accident low and constant, particularly during the moderately hazardous trials. The formal approach to hypothesis development used in this manuscript, as well as the designs of Studies 3 and 4, provides important insights into this failure to fully compensate, beyond those provided by previous research.

For instance, low levels of safety behavior have been attributed to inaccurate assessment of environmental hazardousness (e.g., Bahn, 2013), as well as limited knowledge of appropriate behaviors (e.g., Griffin & Neal, 2000). However, our formal model indicates that individuals are likely to under-allocate resources toward safety behavior within moderately hazardous environments, independent of these factors. Self-regulatory theory and data suggest individuals are likely to respond proportionally to increased hazardousness, yet this contrasts with the sharp, nonlinear increase in safety behavior that is *needed* to fully offset hazards. Furthermore, in Studies 3 and 4 participants were given explicit information regarding the level of hazardousness, and the safety behaviors were simple and easy to learn. Yet even under these ideal conditions, most individuals failed to exhibit the pattern of safety behavior needed to minimize accidents. We believe it is simply not obvious to most individuals that a sharp increase in safety behavior is needed to fully offset increasing hazardousness. As such, our results provide new insights into previous failures to observe full compensation for hazardousness.

9.2.3 | Incorporating accident severity and individual differences into the model

In this manuscript we conceptualized hazardousness as the *likelihood* of an accident occurring within a given timeframe if no precautions (i.e., safety behaviors) are taken to prevent it. Yet, the potential *severity* of an accident is also likely to be an important determinant of safety behavior (Beus & Taylor, 2018; Brewer et al., 2007). We argue that severity can be incorporated into our model as a determinant of the maximum probability of an accident that an individual is willing to accept, which is represented by "R" in our equations. In particular, we expect individuals to be more willing to accept the chance of a mildly severe accident occurring, relative to a highly severe accident. For example, individuals can be expected to be more tolerant of an accident when using a hand saw to prune a tree, relative to when using a chainsaw.

Along these lines, the R parameter can also be used to incorporate individual differences into this model. For example, risk propensity (Blais & Weber, 2006) may be expected to be positively correlated with tolerance for accidents. Likewise, whereas prevention focus (Lanaj et al., 2012) and conscientiousness (Beus et al., 2015) are positively correlated with safety behavior, we suggest that these effects may be mediated by their effect on R. For instance, highly conscientious individuals may behave more safely than their less conscientious counterparts because highly conscientious individuals have a relatively low tolerance for accidents. Lastly, individual differences may moderate the degree to which the maximum acceptable probability of an accident is influenced by the potential severity of the accident.

Unfortunately, testing these predictions is largely beyond the scope of the current research. In particular, the severity of accidents was held constant in Studies 3 and 4. Likewise, we did not directly measure participants' maximum acceptable probability of an accident. Although we did collect individual differences in Study 3 (SOM) and Study 4 (Footnote 9), these individual differences did not influence safety behaviors or accidents. Yet, this may have been driven by the experimental designs. In particular, in Study 4 the value for R was explicitly assigned, and in both studies the trade-off between speed and safety, and the associated incentives, were narrowly defined. Actual work contexts are far more complex, with additional factors at play. Thus, we encourage future research that is designed to examine how factors like potential accident severity and individual differences affect individuals' tendency to under-allocate time and effort to safety behaviors within moderately hazardous work environments.

9.3 | Practical implications

The results from the current research indicate that many individuals lack critical safety knowledge and skills (Burke et al, 2006; Griffin & Neal, 2000), as well as the situational awareness (Endsley, 2021; Stanton et al., 2001) needed to offset the hazardousness of their work environments. Specifically, in Studies 3 and 4 the safety behaviors were easy to enact, and the level of hazardousness was perfectly known going into each trial. In Study 4, the precise manner in which safety behavior and hazardousness combined to affect accidents was also known to participants. Yet, even under these optimal conditions, most individuals under-allocated time and effort to safety behaviors during the moderately hazardous trials. This indicates that most participants were not aware of the need for a sharp increase in safety behaviors in response to relatively small increases in hazardousness. Although future research is needed to replicate the results of the current research across different tasks and contexts, the current research provides initial insights into how workplace safety training programs may be designed to help individuals avoid accidents under moderately hazardous conditions

First and foremost, to avoid under-allocating resources to safety behaviors in moderately hazardous environments, workers can be informed about this issue. Thus, safety training can involve showing Figure 2 to workers and explaining the need to increase safety behavior sharply in response to small increases in hazardousness. Moreover, training should help workers develop situational awareness, which is characterized by the ability to not only perceive hazards in the environment, but also synthesize this information and identify the appropriate course of action. Thus, training programs should identify job-specific examples of hazardous conditions, specific safety behaviors to offset those hazards, and consequences (e.g., accidents) for not enacting safety behaviors. Future research should be conducted to assess the degree to such an intervention is effective for helping individuals avoid under-allocating time and effort to safety behaviors under moderately hazardous work conditions.

Finally, in some contexts, it may be better to maximize safety behaviors at all times. That is, there may be scenarios in which ensuring workers adjust their safety behaviors appropriately (a la Equation 3) requires more time and effort than enforcing a policy of maximizing safety behaviors. For example, a construction company may require employees to wear fall protection when working at *any* height, thereby eliminating the need for individual workers to determine the degree of safety behavior necessary for the setting. However, employees tend to be resentful of rules that are perceived to be unnecessary or unfair, and compliance often suffers as a result (e.g., Dahling et al., 2012; Debono et al., 2013). Thus, organizations should balance these costs and benefits to identify the most appropriate and reasonable safety policy.

9.4 | Strengths and limitations

A key strength of the current research is the use of multiple studies, each of which address limitations of the others. Studies 1 and 2 provide evidence for an inverted-U relationship between hazardousness and accidents within natural work settings. Yet, Study 1 is limited by the fact that data were aggregated to the occupation level of analysis. Although Study 2 addressed this limitation with incident-level data, neither study contained safety behavior data. Studies 3 and 4 addressed this limitation using experimental studies in which hazardousness could be manipulated and both safety behavior and accidents could be unobtrusively observed. However, these studies were necessarily artificial, lacking the richness of context present in Studies 1 and 2. Nonetheless, as a set, these four studies provide consistent support for our predictions.

Studies 3 and 4 also balanced limitations regarding the role of randomness in determining accidents. In Study 3, it was possible for participants to eschew safety behavior and still not experience an accident, simply by chance. This is characteristic of many work outcomes (Vancouver et al., 2016). Conversely, in Study 4 accidents were solely determined by participants' behavior; there was no chance component. Although this represents a limitation to the generalizability of Study 4′s results to more natural settings, there are nonetheless settings in which chance plays little or no role in determining outcomes. For instance, when taking a hot pan out of the oven, there is virtually no chance of avoiding a burn if the proper precautions are not taken to protect one's hands. More importantly, we observed the same pattern of results across both studies. Therefore, individuals are generally not adept at preventing accidents under moderately hazardous conditions, regardless of whether or not luck is a factor.

Given the fact that Studies 3 and 4 used simulations, there may be concerns regarding the degree to which the results generalize to natural environments. We argue that these simulations provide reasonable analogs for the trade-off between safety and productivity at work. Indeed, experimental research provides an important complement to field studies (Highhouse, 2009; Podsakoff & Podsakoff, 2019). For one, experiments allow for stronger causal inferences, relative to field studies. More so, it is not possible to randomly assign workers to hazardous work conditions, and it is practically infeasible to unobtrusively observe safety behaviors repeatedly over time within actual work environments. Therefore, Studies 3 and 4 provided a valuable complement to Studies 1 and 2 in the current manuscript.

Along these lines, we observed the same inverted-U relationship between hazardousness and accidents across all studies. Although participants were not in physical danger in Studies 3 and 4, there were negative outcomes (loss of payment) associated with accidents in these studies. Such financial penalties model real work settings, as accidents are often tied to various negative outcomes (e.g., censure, demotion, termination). Additionally, the studies required trade-offs between goals (i.e., productivity and safety). This is a common element of work simulations, both for studies designed to assess safety behavior (Beck et al., 2017; Wallace et al., 2008) and studies of basic goal prioritization processes (e.g., Ballard et al., 2016; Schmidt & DeShon, 2007). Thus, although Studies 3 and 4 lacked physical fidelity to actual work tasks, they had high psychological fidelity, which is arguably more important (Kozlowski & DeShon, 2004). Nonetheless, future research should use alternative experimental paradigms to demonstrate that the current results are not dependent on the specific simulations used in Studies 3 and 4. For instance, it may be productive for future research to vary types of hazards, the degree to which hazards can be perceived, and the complexity of safety behaviors.

Finally, it is important to acknowledge that the purpose of this manuscript was to understand the interrelationships among hazardousness, safety behaviors, and accidents experienced by individuals. As such, the degree to which the results presented here generalize to organization-level accidents remains to be seen. Large scale accidents (e.g., Deepwater Horizon, Space Shuttle Challenger) tend to be complex events with multiple causes, often emerging as the result of a "perfect storm" of circumstances. Nonetheless, almost invariably these events can at least partly be attributed to faulty human decision-making (Moorhead et al., 1991; Reader & O'Connor, 2014). The current manuscript suggests that failure to sufficiently react to moderate increases in hazardousness may eventually manifest as these types of large-scale accidents. Future research is needed to explore this possibility.

10 | CONCLUSION

It is unreasonable to expect workers to maximize safety behaviors at all times. Doing so is inefficient and comes at the expense of productivity. Instead, individuals tend to adjust safety behaviors to meet the demands of the situation. Although most individuals understand the need to use safety behaviors to compensate for hazardousness in their work environments, most people also underestimate the *degree* to which safety behaviors must be increased, particularly within moderately hazardous contexts. As a result, the highest incidence of accidents occurs in moderately hazardous work environments. Thus, to keep accidents to a minimum, additional emphasis on moderately hazardous work environments is warranted.

DATA AVAILABILITY STATEMENT

Data and syntax are openly available on the Open Science Framework (https://osf.io/yx927/).

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ENDNOTES

[1] There are also random determinants of accidents, such that accidents can and do occur even when all possible precautions against them have been taken. This can be accounted for by adding a random error term to Equation (1). However, doing so only produces "noise" variance, and does not change the conclusions of this manuscript. Thus, for the sake of simplicity we have omitted random determinants of accidents.

[2] In the current paper we consider a special case in which individuals are *perfectly* aware of all environmental hazards. Vancouver et al. (2010) used a similar approach, assuming goal progress was perceived perfectly. We made this simplifying assumption to demonstrate that failure to fully compensate for hazards does not depend on inaccurate perceptions of hazardousness. Nonetheless, we acknowledge that individuals can be inaccurate in their assessment of hazards (Heimer, 1988; Weinstein, 1989), often in systematic and predictable ways (Tversky & Kahneman, 1974). In the Supplemental Online Materials (SOM) we incorporate hazardousness perceptions. Furthermore, we demonstrate that doing so does not change the implications of our model.

[3] Incidents with missing hazardousness data were likely to involve slightly larger vessels ($t(39232) = 5.16$, $SE = .01$, $p < .001$, Glass $\delta = .05$) and vessels with fewer people on board ($t(28850) = -9.67$, $SE = 1.08$, $p < .001$, Glass $\delta = -.12$). There was no significant difference in serious injuries (i.e., accidents) across incidents for which hazardousness data were missing vs. not missing ($t(40497) = .48$, $SE = .002$, $p = .629$, Glass $\delta = .005$).

[4] There were also some incidents for which sea conditions were coded as a categorical variable (e.g., "ice patches"). These incidents were coded as missing and were not included in the data set.

[5] The database includes several variables that could potentially be used to operationalize accidents. Each record included the number of serious injuries, minor injuries, deaths, and people overboard. However, these variables were virtually uncorrelated (mean $r = .04$, max $r = .07$), meaning computing a composite of these variables was inappropriate. Instead, we report the results using serious injuries as the dependent variable in text, and we report results using the remainder of the variables in the SOM.

[6] We'd like to thank an anonymous reviewer for pointing this out.

[7] We plotted hazard values from 0 to 4 as these values represent 99.9% of the observations. The interpretation of the results does not change when the control variables are excluded from the model.

[8] Because this manipulation creates three discrete hazardousness levels, it may be considered more appropriate to represent the manipulation in our analyses using two dummy variables. However, because these conditions represent numeric values (specifically, the proportion of unstable shelves) and the values increase by a consistent amount between conditions, it is appropriate to treat this variable as continuous. Indeed, the results are virtually identical (i.e., within rounding error) when dummy variables are used. However, the set of dummy variables is more challenging to interpret, relative to a single continuous variable. Thus, for clarity we treat hazardousness as a continuous variable.

[9] Specifically, we administered the 30-item domain-specific risk-taking (DOSPERT) scale (Blais & Weber, 2006). This scale was included for exploratory purposes. DOSPERT scores were not correlated with sensitivity ($r = .09$, $p = .433$), and including DOSPERT scores in our analyses had no substantive influence on the results. Therefore, we do not consider this measure in the remainder of the manuscript.

[10] There were also four participants who displayed very little (or zero) variance in safety behavior across the trials (#8, 23, 34, and 46). Deleting these participants had no meaningful effects on the hypothesis tests. Furthermore, although this pattern might represent lack of engagement with the task, it is equally plausible that this pattern represents an intentional strategy. Therefore, data from these participants were retained.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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