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Learning from error: The influence of error incident characteristics ☆

Gert J. Homsma [a,*], Cathy Van Dyck [b], Dick De Gilder [b], Paul L. Koopman [a], Tom Elfring [c]

[a] Department of Work and Organizational Psychology, Faculty of Psychology and Pedagogics, VU University, Amsterdam, The Netherlands
[b] Department of Public Administration and Organization Science, Faculty of Social Sciences, VU University, Amsterdam, The Netherlands
[c] Department of Management and Organization Science, Faculty of Economics and Business Administration, VU University, Amsterdam, The Netherlands

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Abstract

This study investigates the influence of error incident characteristics on organizational learning among operators in the chemical process industry. The study asks operators to describe recently occurred error incidents at time 0 ($n=87$), followed up by measurements for learning 6 weeks later ($n=48$). Organizations learn more from error incidents with more severe consequences. Severity of consequences relates positively to learning. When consequences are more severe, communication about an error is higher. Communication is subsequently related to learning. Error incidents without imminent negative consequences, however, can also be a platform for learning. This research recommends attention towards the promotion of learning from conditions that do not necessarily encourage employees to learn.

Keywords: Learning from error; Error consequences; Communication about errors

1. Introduction

Executives as well as scientists increasingly acknowledge that errors cannot always be prevented in organizational contexts (Edmondson, 1996; Garud et al., 1997). "Mistakes are inevitable, given the present state of decision making and the dynamic environment facing organizations" (Hartley, 1994, p. 2). As error incidents can lead to a variety of negative outcomes (e.g., production and quality losses, loss of clients or even physical injuries), employees need to be prepared for error handling. Furthermore, errors can lead to positive outcomes such as learning (Nonaka and Takeuchi, 1995).

The present study investigates conditions that may induce learning from error. Scientists have argued that organizations can profit from errors. Arnold and Roe (1987), for example, have stated that errors can be highly informative when people discover why errors occur and how they should be corrected. Conditions under which organizations actually learn from errors are, however, unclear. Scholars have proposed appealing ideas, frameworks and concepts on learning from unsuccessful actions such as errors (e.g., McGrath, 1999; Rochlin, 1999; Sitkin, 1992; Weick, 1987), but empirical evidence remains scarce.

Theoretical contributions on learning from unsuccessful actions, furthermore, have resulted in divergent lines of thinking. Some scholars argue that decision-makers often overlook small deviations from expected outcomes as these deviations appear too insignificant to learn from (Cannon and Edmondson, 2005), while others argue that small losses are effective in the activation of learning (Sitkin, 1992). Further, the observation that organizations often learn very little from their errors is disturbing (Baumard and Starbuck, 2005). This study contributes to the theoretical body of research about learning from error. A better understanding of those conditions that induce or hinder learning has the potential to pave the way for research directed at a more effective use of errors for learning in practice.

For organizations to profit from positive outcomes of error, obtaining a better understanding of the circumstances that encourage employees to learn from error is critical. The goal of the present study is to identify those conditions by examining how error incident characteristics affect learning. Severity of

☆ We thank Natasja Vincent for her assistance in collecting the data.
* Corresponding author. Department of Work and Organizational Psychology, VU University, Van der Boechorststraat 1, 1081 BT Amsterdam, The Netherlands. Tel.: +31 20 598 8722/00.
E-mail address: gj.homsma@psy.vu.nl (G.J. Homsma).

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error consequences, communication about errors and perceived lack of personal control over the error cause are assessed as possible determinants of learning from error. After sharpening the terminology of the key concepts, hypotheses are developed about the influence of error incident characteristics on learning.

1.1. Learning from error

Errors are generally understood as deviations between the intended and actual outcome of an action. Following the action theory perspective, human error is built up around three defining aspects (Frese and Peters, 1988; Rasmussen, 1987; Reason, 1990); (1) errors are unintentional; (2) occur only in goal directed action; and (3) the error-maker should have known better, implying that the error was potentially avoidable and not chance based. Although the concept of human error is related to failure, the focus in this paper is solely on human error. Besides errors, failure namely also comprises non-attainment of goals by violations (intentional), unavoidable random external events (e.g., lightening strikes) or sabotage (intentional damage).

In popular speech, the term "error" often refers to both the error itself as well as the negative consequences. It is, however, important to realize that an error and error consequences are two distinct things. From a psychological perspective, an error itself is defined as an action that fails to produce the intended result, without implying anything about the nature of the consequences. The distinction between an error and its negative consequences is essential because the same erroneous action may result in a variety of negative consequences, depending on the situation or context in which the error occurs (Van Dyck, 2000). The same erroneous action, for example—administering a double dose of a medicine—can lead to a variety of negative consequences. Administering two aspirins instead of one will hardly lead to any negative consequences. The identical erroneous action, however, can lead to grave consequences when mistakenly administering a double dose of a more serious medicine (e.g., colchicines or blood diluents).

In the organizational learning literature, deviations between action and outcome (e.g., errors, incidents, discontinuous events, breakdowns) are assumed to offer room for learning (Argyris, 1992). Lipshitz, Popper and Friedman (2002; p.81–82) view learning as "a cyclical process involving the evaluation of past behavior, the discovery of error or opportunity, the invention of new behaviors, and their implementation." The evaluation of past behaviors and acting upon the awareness that errors hold useful information are indeed considered as important practices to learn from error (Van Dyck et al., 2005).

This study contributes to the organizational learning literature by investigating under which conditions employees learn from error. According to Kim (1993), knowledge on how employees make sense and react is at the heart of organizational learning. He argues that one challenge in the field of organizational learning is to develop knowledge under which situations individuals (do not) exploit learning opportunities in the social context of the organization. Knowledge on how employees handle and react to situations is a hallmark for creating new devices and tools to (1) better exploit potential learning opportunities; and (2) create mechanisms to exploit and transfer learning to the organizational level.

1.2. Severity of error consequences

Error incidents challenge the status quo and promote learning (Cyert and March, 1963; Levitt and March, 1988; Sitkin, 1992). People are more motivated to learn when things go wrong (Argyris, 1992; Weiner, 1985). Looking at the literature on retrospective case studies, especially incidents with severe negative consequences tend to spur research on learning behavior (e.g., Birkland, 2004; Perrow, 1984; Toft and Reynolds, 2005). Interest in major accidents such as the Chernobyl meltdown is understandable. The severe negative consequences point out that things have gone wrong and knowledge about the precursors of this outcome should be obtained. They signify the necessity to improve or change routines to prevent the incident from reoccurring.

Industrial accidents with severe negative outcomes often initiate learning. However, error incidents without severe negative consequences occur much more frequently in organizations than incidents with severe negative outcomes (Ramanujam and Goodman 2003). Organizations, however, often fail to learn from these incidents (Baumard and Starbuck, 2005). In the same line of reasoning Cannon and Edmondson (2005), argue that small deviations from expected outcomes are often overlooked because they appear to be too insignificant to make use of their learning potential.

The more severe negative consequences get, the more people are induced to learn. Empirical research supporting this line of reasoning, however, is not available. Thus far, only one quasi-experimental study has investigated the influence of error consequences on learning. Based on a scenario study, managers show more inclination to recommend learning, when outcomes become more severe (Zakay, Ellis and Shevalski, 2004). This leads to the following hypothesis. Hypothesis 1: Severity of error consequences relates positively to the generation of new ideas and insights and the implementation of improvements.

1.3. The role of communication on learning from error

Several scholars argue that communication about errors facilitates learning from error (Carroll, 1998; Mathieu et al., 2000). Communication is one of the most important conditions for learning from error to occur (Edmondson, 1996; Van Dyck et al., 2005; Rochlin, 1999). Edmondson emphasizes that the creation of an environment that fosters open reporting, active questioning and frequent sharing of insights supports learning from error. Similarly, Van Dyck and colleagues argue that communication about errors is pivotal to the promotion of learning and innovation as it leads to the development of shared knowledge about errors. Rochlin stresses the importance of communication when dealing with human error. He argues that eliminating human error from the workplace is an interactive, dynamic and communicative act that facilitates organizational learning. Communication about errors gives employees the opportunity to generate new ideas and insights by incorporating

viewpoints of others. This process should aid the identification of possibilities for improvements that help to avoid the same error from reoccurring.

Communication about error affects learning. In practice, however, communication about errors is not obvious, nor is covering up uncommon (Van Dyck et al., 2005). Employees can be hesitant to share their errors as they are (1) uncertain about the reactions of colleagues; (2) afraid that their errors could damage their career; and (3) try to avoid potential blame or reprimands (Cannon and Edmondson, 2005; Husted and Michailova, 2002). These reactions towards errors all have their origins in the organizational view towards errors. As errors can lead to a variety of negative outcomes, many organizations tend to punish error occurrence, thereby discouraging open communication. When there is no explicit shared belief that making mistakes will not be held against you, the willingness to engage in open discussion will be low (Edmondson, 1996).

Many employees keep silent about their errors. However, the degree of negative consequences might mitigate this behavior. The first reason to expect that communication may mediate the relation between severity of consequences and learning from error is that the impact and visibility of errors with severe consequences is often higher than for errors without negative consequences. The visibility and the impact of negative consequences, in other words, makes it necessary for the employee to communicate, because there is no opportunity for covering up. Errors with severe negative consequences in that sense 'force' employees to engage in communication. Moreover, Cannon and Edmondson (2005) argue that misinterpretation of the usefulness of 'small failures' hinders learning. They argue that 'small failures' often do not lead to communication because they appear to be too insignificant to make use of, whereas catastrophic failures argue for the necessity of learning due to their negative impact. This leads to the following hypothesis. Hypothesis 2: Communication about error mediates the relation between severity of error consequences and the generation of new ideas and insights and the implementation of improvements.

1.4. Perceived personal control

When people perceive flaws resulting from their actions, they try to identify the underlying causes (Weiner, 1985, 1986). After error occurrence, these assigned causes form the guide for subsequent action (Homsma et al., 2007). People have a basic desire to believe that they have control over unsuccessful actions (Cannon and Edmondson, 2005; Langer, 1975). This illusory belief of control may form a barrier for learning as people overestimate the level of control they have over the causes of error. Unrealistic optimism may lead people to ignore legitimate risk and to fail to take measures to offset those risks (Taylor and Brown, 1988, p. 204). As Cannon and Edmondson (2005, p.302) argue "positive illusions [of]… control and efficacy may be incompatible with an honest acknowledgement of failure, and thus, while promoting happiness, can inhibit learning." This implies that errors without serious negative consequences may not induce learning as illusions of control make people feel able to prevent the error from reoccurring without additional learning activities. A certain amount of uncertainty or crisis is necessary to engage in learning oriented behavior (Miller and Friesen, 1980; Fiol and Lyles, 1985; Daft and Weick, 1984). Fiol and Lyles argue that lack of experienced control is a prerequisite for learning to occur. Learning is induced by events that cannot be tackled by the usual way of doing things. Ambiguity and insufficiency of solutions in existing procedures thus seem to make learning more likely. Lack of perceived control over the situation, in other words, makes learning more likely (Fiol and Lyles; Miller and Friesen, 1980).

In a scenario study conducted by Zakay et al. (2004), moreover, managers reported a greater need to enhance control when error consequences become more negative. When people perceive a lack of personal control over the underlying error causes, they are more inclined to put effort into improvement of existing behavioral procedures in order to gain control over such error incidents. This discussion informs the following hypothesis. Hypothesis 3: Lack of personal control over the error cause relates positively to the generation of new ideas and insights and the implementation of improvements.

2. Materials and methods

2.1. Sample

Seventy-two operators (92% male) active in the chemical process industry took part in the study. The operators came from one middle-sized company (approximately 200 employees) specialized in the field of refining coal tar. Operators in the participating company are involved in the refining process of crude coal tar into intermediates for industrial purposes such as resins. Mean age of the operators was 39.7 (SD = 8.4).

The data were collected at time intervals. At time 0, participants received a questionnaire in which they were asked to describe a recent error incident. At time 1, 6 weeks later, measurements for learning followed. Data collection at time 0 yielded reports of eighty-seven error incidents. Forty-eight error incidents were followed up by a time 1 measurement. The error incidents form the unit of analysis. Additional examination of the error incidents revealed no operator specific effects. Analyses rerun on data with only one error incident per operator revealed identical correlations when compared to the overall sample. The effects of the reported mediation were also in the same order of size. The sample of error incidents can be treated as independent, even if reported by the same operator.

2.2. Procedure

In total, the participants received two time 0 questionnaires. The time 0 questionnaires were distributed with a 6 week's interval. Each time 1 questionnaire was presented 6 weeks after the corresponding time 0 questionnaire. The distributed t_0 and t_1 questionnaires jointly form the error tracking instrument (ETI; Van Dyck, submitted for publication), which is developed to measure subsequent action after error occurrence.

At time 0, participants described an error that had recently occurred. Next, the participants described the main cause for the error to occur (see Table 1 for examples of reported error incidents and error causes). After the participants had written down an error and error cause, questions about the severity of the error consequences (open-end as well as Likert scale), communication about errors (open-end) and personal control over the error cause (Likert scale) followed.

At time 1, measurements for the occurrence of learning from error in the 6 weeks interval followed. Participants were asked to indicate whether the error had led to new ideas and insights (Likert scale) and whether improvements had been implemented to prevent the reoccurrence of the described error (open-end and Likert scale).

2.3. Coding of qualitative material

To process the open-end questions, two psychology students familiar with the subject coded the data. The coders were trained in using the coding scheme developed by Van Dyck, (submitted for publication). Ten randomly drawn questionnaires were used for training purposes. The inter-rater reliabilities based on these ten questionnaires were excellent (Cohen's kappa's ranging from kappa = .96 to kappa = 1). After the training session, the two coders then independently rated all remaining questionnaires (see Measures section for overall inter-rater reliabilities). Whenever the raters differed on a score, they discussed the item and tried to achieve conformity. When the raters did not reach conformity, rater 1, the person with most expertise, decided on the score.

Table 1
Examples of error incidents and reported causes

Reported error incident	Reported error cause
I fixed the viscosity of a resin solution at the wrong temperature. I fixed the viscosity at 20 °C instead of 30 °C.	I forgot to adjust the right temperature.
The wrong premix-tank was mistakenly made anhydrous.	The message was misunderstood due to noise using the walky-talky.
A shut-off valve between two tanks was not closed after the completion of a charge. As the tanks were still attached, contamination arose when another charge followed.	The shut-off valves were not carefully checked.
I did not correctly clear a line while working on it. Therefore, residual cargo poured out when I opened the line.	I did not follow the procedures correctly.
A cooling water pipe froze. Early March, the temperature unexpectedly dropped. Although normal precautions were taken, the specific pipe was not secured by the pipe line heating system.	Due to a steam leakage, the water pipe was not secured by the heating system. As nobody thought that it would freeze in early March, this flaw was not adequately managed.
An oil product was pumped on to the terrain through a valve, as the lining system was inadequately aligned.	The work pressure is too high during certain operations as to many actions have to be done at the same time. Therefore, I did not carefully check whether or not the lining system was correctly aligned.

2.4. Measures

2.4.1. Severity of error consequences

This variable was measured by a closed Likert item as well as an open-end question. Using a Likert scale, operators rated the severity of the error consequences ranging from 1 (the error consequences were not severe at all) to 5 (the error consequences were extremely severe). In the open-end question participants described the error consequences. These open-end answers were coded on a scale ranging from 1 (there were no error consequences; e.g., "We ascertained that there was no water interfering the production process") to 3 (the error consequences were severe; e.g., "noxious fumes were discharged during an emission process", kappa = .96). The open-end and the closed component were highly related ($r = .75$; $p < .01$). Severity of consequences was operationalized by the mean standardized score of the open-end and the closed component.

2.4.2. Lack of perceived personal control

Perceived personal control was measured by three items of the Causal Dimension Scale II (CDSII; McAuley, Duncan, and Russell, 1992). For this study, the root of each item was changed from "Is the cause something" as used in the CDSII to "Is the cause of the error something"). For example, "Is the cause of the error something you can regulate"—1- 2- 3- 4- 5—you cannot regulate; $k = 3$, Cronbach's alpha = .84). Each item was thus measured on a 5-point scale ranging from 1 (e.g., You can regulate) to 5 (e.g., you cannot regulate).

2.4.3. Communication about errors

The variable communication about errors was operationalized by an open-end question. The operators described whether, and if so, to what degree error-related communication had taken place at their division. The answer was coded on a scale ranging from 1 (no communication about the error; e.g., "I didn't discuss the error.") to 5 (extensive communication about the error; e.g., "Information about the error incident was exchanged to the persons concerned", kappa = .98).

2.4.4. Generation of new ideas and insights

At time 1, operators described whether the error had led to new insights and ideas. The verbatim text of this question was: "Thinking back to the error you have described at [time 0]; did this error lead to new insights and/or ideas within the organization?" Using a Likert scale, participants rated to what degree the error had led to new ideas and insights ranging from 1 (the error did not lead to new ideas and insights) to 5 (the error led to a great extent of new ideas and insights).

Generation of new insights and ideas was also measured by an open-ended question. For this variable, however, only seven operators actually described insights and ideas that had arisen from the error incident, whereas 17 operators reported that the error had led to a certain degree of new ideas and insights on the 5-point Likert scale measure. Thirty operators reported no new ideas and insights on the Likert scale measure.

T-tests tentatively suggest that the open-ended item may well be a valid measure. The mean degree of negative consequences

Table 2
Means, Standard Deviations, Kappa's/Cronbach's Alpha's, and correlations among the variables studied

	Variables	Scale	Kappa/ α	N	M	SD	1	2	3	4	5
	T_0 error incident										
1.	Severity of consequences	n.a.	n.a.	83	−.09	.89	–				
2.	Lack of personal control	1–5	.84	86	3.30	1.32	.24*	–			
3.	Communication about errors	1–5	.96	79	3.92	1.47	.42**	.07	–		
	T_0 learning from error										
4.	Generation of new insights and ideas	1–5.	n.a.	48	1.65	1.02	.33*	.31*	.35*	–	
5.	Implementation of improvements	n.a.	n.a.	43	−.23	.88	.32*	.19	.35*	.46**	–

Note. N (i.e. number of incidents) is 87 at T1 and 48 at T2. Severity of consequences and implementation of improvements are based on the mean standardized score of an open-end and an closed component. * $p<.05$; ** $p<.01$, all tests are two-tailed.

for the seven incidents for which the open-ended question was filled in (standardized mean=.71) was higher than the mean of the remaining part of the sample (standardized mean −.17), $t(82)$, 2,67; $p<.01$. The severity of consequences was thus significantly higher for the seven error incidents for which the open-ended question was filled in than for the other error incidents. Combining the open-ended measure with the Likert-scale item, however, would lead to a huge data loss because only seven participants filled in the open-ended question. The open-end question was, therefore, discarded from further analyses.

2.4.5. Implementation of improvements

At time 1, operators indicated whether improvements had been implemented after error occurrence. The verbatim text of this question was: "Thinking back to the error you have described at [time 0]; since then, have corrective measures been taken to prevent this error from reoccurring?" Based on a Likert scale, participants rated whether improvements had been implemented on a scale ranging from 1 (no improvements have been implemented) to 5 (improvements were implemented to a great extent). In the open-end question, the participants described which improvements were implemented. The answers were coded on a scale ranging from 1 (there was no implementation of improvements; e.g., "not applicable, no improvements have been implemented") to 3 (improvements were fully implemented; e.g., "Based on the error incident, explosion-proof fork lift trucks were purchased", kappa=.98). The open-end and the closed component were highly related ($r=.73$; $p<.01$). Implementation of improvements was operationalized by the mean standardized score of the open-end and the closed component.

3. Results

Table 2 presents the means, standard deviations, and correlations among the variables studied. Results show that severity of error consequences is significantly related to the generation of new ideas and insights and implementation of improvements over time. Severity of consequences at t_0 is related to higher generation of new ideas and insights ($r=.33$; $p<.05$) and higher implementation of improvements ($r=32$; $p<.05$) at t_1. Hypothesis 1 is supported.

Hypothesis 2 predicts that communication about errors mediates the effect of severity of error consequences on the generation of new ideas and insights and implementation of improvements. According to Baron and Kenny (1986) one can speak of mediation if (1) there is a significant relation between predictor and mediating variable; (2) there is a significant relation between mediator and dependent variable; (3) there is a significant relation between predictor and dependent variable; and (4) the significant relation between predictor and dependent variable ceases to be significant when the mediator is taken into the equation. The first three conditions were met. Table 2 shows that severity of error consequences is significantly related to the mediator communication about errors ($r=.42$, $p<.01$) and the dependent variables generation of new ideas and insights ($r=.33$, $p<.05$) and implementation of improvements ($r=.32, p<.05$). Communication about errors in turn is also significantly correlated with generation of new ideas and insights ($r=.35$, $p<.05$) and implementation of improvements ($r=.35$, $p<.05$). To test condition 4, a regression analyses was performed. Table 3 shows that the relations between severity of error consequences and generation of new ideas and insights ($\beta=.16$, $p=.33$) and implementation of improvements ($\beta=.20, p=.27$) cease to be significant when communication about errors is taken into the equation. These findings suggest that communication about errors mediates the relation between severity of error consequences and learning.

To test the significance of the mediator communication about error, we performed the Sobel test (Preacher and Hayes, 2004). The Sobel test revealed that communication about error was not a significant mediator in the relation between severity of

Table 3
Standardized hierarchical regression analysis of severity of consequences and communication about errors on learning from error

Predictor / step	β	R^2	F_{R^2}	ΔR^2	$F_{\Delta R^2}$
Effects on generation of new ideas and insights[1]					
Step 1		.08	3.80#	.08	3.80#
Severity of consequences	.29#				
Step 2		.14	3.20#	.06	2.47
Communication about errors	.26				
Severity of consequences	.16				
Effects on implementation of improvements[2]					
Step 1		.10	4.27*	.10	4.27*
Severity of consequences	.32*				
Step 2		.14	3.07#	.04	1.78
Communication about errors	.24				
Severity of consequences	.20				

Note. [1] $N=42$; [2] $N=38$; #$p<.10$; * $p<.05$, all tests are two-tailed.

consequences and learning. Respectively, Sobel Z=1.21, $p=.21$ for the relation between severity of consequences and integration of new insights and ideas and Sobel Z=1.46; $p=.14$ for the relation between severity of consequences and implementation of improvements. Hypothesis 2 was not supported.

Results show that lack of personal control is significantly related to the generation of new ideas and insights over time. When operators perceive less personal control, there is a higher generation of new ideas and insights ($r=.31$, $p<.05$). Lack of personal control, however, is not significantly related to the implementation of improvements ($r=.20$, *ns*). Hypothesis 3 is partially supported.

4. Discussion

As predicted, this research shows that error incident characteristics influence learning from error. Severity of consequences relates positively to learning from error. When error consequences are more severe there is higher generation of new ideas and insights and higher implementation of improvements in the weeks following the error occurrence. Severity of error consequences, thus, induces learning from error. Although incidents with small losses are identified as fruitful learning opportunities (Sitkin, 1992), this research indicates that employees do not seize these possibilities. A possible explanation for this result might be the current call for efficiency and high production demands on employees (Hollnagel, 2002). These high demands on employees may decrease the perceived necessity or opportunity to adjust mismatches between goal oriented action and task outcomes as time pressure compels employees to work as efficient as possible (Rasmussen, 1997). That is, only if errors result in relatively severe consequences, a profound need for learning is perceived. Additional research should incorporate perceived need for learning to examine this line of reasoning.

Although the study does not support the prediction that communication mediates the relation between severity of error consequences and the two learning variables (the significance of the beta coefficient of severity of consequences drops, but the beta of communication about errors does not come out significant either), severity of consequences is strongly related to communication about errors which is subsequently related to both generation of new ideas and insights and implementation of improvements. This finding provides some evidence for the proposition that communication about errors is an important requisite for learning from error (Edmondson, 1996; Van Dyck et al., 2005). Argued the other way around, lack of communication about errors probably is an important reason that most organizations fail to learn from error.

The findings suggest that employees do not automatically share knowledge about errors, but that severe error consequences are likely to induce communications. Why do employees keep silent about errors that do not lead to severe negative consequences? One explanation is that shared organizational attitudes held about error influence communication about errors. An intolerant view towards errors for example, more easily elicits a reprimand than praise upon error reporting. In such an organization, employees most likely think twice before discussing their errors. Future research should include aspects of the organizational culture to explain why employees hesitate to communicate about errors.

Lack of perceived personal control over the error cause also affects learning from error (H_3). When operators perceive a lack of control over the error cause, there is a higher generation of new ideas and insights. The findings support the proposition that lack of control is a prerequisite for learning to occur (Duncan, 1974; Fiol and Lyles, 1985). The prediction that lack of personal control over the error cause is related to the implementation of improvements is, however, not supported. Although correlations reveal a trend in the predicted direction, it is not significant.

Error incident characteristics predict learning after error occurrence. Severity of consequences, lack of personal control over error causes and communication about error are conditions that induce learning from error. Future research should examine the barriers that prevent organizational learning from error when (a) consequences are not severe; and (b) when there is *no* lack of personal control over the error cause. Employees may fail to learn from error as high production demands may decrease the opportunity to take time to learn from incidents that seem insignificant. This proposition can be verified in future research by incorporating variables concerning the reasons for employees to engage in learning from error.

4.1. Strengths and limitations

For the first time an empirical field approach examines the conditions that stimulate or hinder organizational learning. An ex ante research design in which employees report and describe errors that occur in their work setting is rare. This study's contributes to this theoretical and experimental body of research. Experimental error training studies, for example, support the notion that errors can have a positive and informative function (Chillarege et al., 2003; Heimbeck et al., 2003). The current research, however, suggests that these findings do not automatically translate to the field. Learning from error in organizational contexts seems to be dependant on error incident characteristics such as severity of consequences and perceived personal control over the error cause. Future empirical research, therefore, should focus on the explanation of this outcome to enable the application of the learning from error research into practice.

The fact that the data are collected at two points in time is an additional strength of the study. Data on the generation of new ideas and insights and implementation of improvements were collected 6 weeks after employees reported an error incident at time 0.

Besides these strengths, the current study also has its limitations. One could raise concerns about the validity of the study measures as several measures have been newly developed. Measures for learning from error, communication about errors and severity of consequences, were not readily available. In order to prevent mono-method bias, the study operationalizes several constructs with one closed Likert item and one open-end question. Unfortunately, the open-end component of one variable (generation

of new ideas and insights) was only filled in by seven operators. The open-end component of generation of new ideas and insights was, therefore, discarded from further analyses. Further, as the research is conducted in the chemical process industry, future research should be aimed at whether the findings also hold in other sectors.

4.2. Implications for practice

This study shows that error incident characteristics affect learning from error. Errors with severe negative consequences and incidents in which employees perceive lack of control over the error cause form a fertile base for learning from error. Yet, error incidents without severe consequences also have considerable learning potential. An important practical implication of this study is that organizations should emphasize that error incidents without severe consequences also have considerable learning potential. Ramanujam and Goodman (2003) show for example that errors without severe consequences occur much more frequently in organizations than incidents with severe negative consequences. Severity of consequences is, therefore, not an appropriate criterion for learning because the same error may result in a variety of consequences, depending on the context in which the situation occurs. Managers should create awareness among their subordinates that the degree of negative consequences is not a valid standard for learning from error. Rather, managers should emphasize that errors with insignificant negative consequences may form the early warning signs that should be taken seriously if future catastrophic accidents are to be avoided (see Sitkin, 1992).

While total elimination of error occurrence is impossible, the present research suggests that organizations should be stimulated to prevent themselves from being bitten twice. From a managerial perspective, attention should be focused towards the promotion of learning in situations that do not necessarily encourage employees to learn. The current research has shown that communication about errors facilitates learning. Managerial attention should create opportunities for the work staff to engage in communication about error in order to allow for the development of shared knowledge about errors. The implementation of discussion groups, for instance, makes it possible for employees to discuss the daily errors they encounter at work (Brown and Duguid, 2000). Opportunities for employees to interact and discuss errors openly may promote organizational learning from those incidents that not necessarily induce learning during the employee's daily activities.

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