Mastering the dual challenges of errors: Risk and uncertainty as contingencies for control and learning

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Abstract

The role of risk and uncertainty as contingencies for error types, control of error consequences and learning is assessed. For this purpose, longitudinal qualitative material on recent errors is gathered in two distinct organizations: A low uncertainty, high risk setting, and a high uncertainty, low risk setting. Results show that setting predicts differential success in control (higher scores for low uncertainty, high risk setting) and learning (higher scores for high uncertainty, low risk setting). Further, setting affects error type, with more high regulation errors in the high uncertainty, low risk setting, and more low regulation errors in the low uncertainty, high risk setting. Findings offer implications for both theory and practice.

Introduction

> *"Given that human error will never disappear from organizational life, an important management issue thus becomes the design and nurture of work environments in which it is possible to learn from mistakes and to collectively avoid making the same ones in the future."* Edmondson (1996, p. 25)

Research has shown that organizational error culture is related to organizational performance. More specifically, organizations where emphasis lies on communication, analysis, correction and learning after error do better (Edmondson, 1996; Van Dyck, Frese, Baer & Sonnentag, 2005). An interesting question, however, is whether this is true for all lines of industry, work environments, and task characteristics alike. And even if so, would identical mechanisms explain error handling – performance relationships?

Traditionally, emphasis in error research has been on high risk industries such as aviation, medicine, and nuclear power plants (e.g., Eisenberg et al., 2005; Helmreich, 2000; Reason, 1997; Welch & Jensen, 2007). As high risk implies the possibility of severe negative error consequences, the issue of prevention of either error itself, or prevention or containment of adverse consequences is highly relevant. Research on High Reliability Organizations (HROs) focuses on understanding the reasons why some organizations are able to avert accidents while others are not. A flexible, learning oriented culture, with an emphasis on communication and trust is one of the characteristics of HROs (Cox, Jones & Collinson, 2006; Roberts & Bea, 2001; Weick & Sutcliffe, 2001).

High reliability is sometimes described as the absence of error occurrence (Pool, 1997; Roberts, 1990; Weick, 1987). Yet, from the same research it has become clear that errors occur even in HROs. What makes HROs highly reliable is not so much absence of errors, but rather the absence of accidents. That is, HROs are capable at averting negative error consequences. Pool (1997, p. 260-261) describes this quality at a high reliable aircraft carrier: "[...] the crew members act as a team, each doing his job and watching what others are doing [...] [a] constant flow of communication helps catch mistakes before they have caused any damage." In a similar vein, Rochlin (1999) reports that HROs tend to reward the reporting of errors, and focus on organizational (i.e. shared) responsibility rather than on blaming the direct actor.

Errors, however, may yield positive consequences as well. There are various examples of errors that have led to great innovations. The accidental development of penicillin is probably the most renowned example (see also Jones & O'Brien, 1991). More recently, research has focused on these positive error consequences such as learning, adaptation and innovation (e.g., Carmeli & Gittell, 2008; Cooke and Rohleder, 2005; Van der Linden et al., 2001, Van Dyck *et al.*, 2005). In sharp contrast to research on possible severe negative consequences, research on positive error consequences is usually not conducted in high risk settings. Instead, training settings (e.g., Frese, 1995; Wilson *et al.*, 2005), or settings with high need for innovation (e.g., Research & Development; Pirola-Merlo, Härtel & Hirst, 2002) are consulted for the study of positive error consequences.

Research in both traditions –high risk versus learning focused- shows that organizational culture is important (Edmonson, 1996; Van Dyck, 2009; Van Dyck *et al.*, 2005; Weick, 1997). In both areas, communication about error comes up as a key feature. It has, however, not been established whether communication (and other error culture facets) is related to outcome variables through similar processes. Literatures on Total Quality Management (Cole, 1998; Hackman & Wageman, 1995; Sitkin, Sutcliffe & Schroeder, 1994), exploitation versus exploration (Holmqvist, 2004, Lunnan & Barth, 2003; March, 1991) and organizational learning (Argyris, 1992; Carroll, Rudolph & Hatakenaka, 2002; Huber, 1991) suggest diffe-

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rent processes for high risk and learning focused settings. Sitkin *et al*. (1994) have argued that Total Quality Management actually comprises two distinct goals resulting in distinct approaches; Total Quality *Control* and Total Quality *Learning*. On the one hand, organizations want to do 'the things they do' without errors (Total Quality Control). They want to exploit the methods that have proven their success (Benner & Tushman, 2003; Lunnan & Barth, 2003), and improve them (single-loop learning; Argyris, 1992, 1996; March, 1991). This implies controlling and auditing known processes, and a focus on reliability and stability. On the other hand, organizations want to be adaptable and innovative (Total Quality Learning), and explore new ideas and methods (Agryris, 1992, 1996; March, 1991), which implies double-loop learning (Crossan, Lane & White, 1999; Weick, Sutcliffe & Obstfeld, 1999) rather than single-loop learning. Both goals of control and learning are valid and important, yet require conflicting strategies (e.g., auditing versus experimentation), which makes it hard to achieve an optimal balance.

As errors may result in either negative (e.g., loss of time, faulty products, accidents) or positive consequences (e.g., learning, innovation and resilience) a similar duality as proposed in TQM arises. The organizational goal of avoiding negative error consequences is conceptually associated with the more general goal of control. The organizational goal of fostering positive error consequences is similarly associated with the more general goal of learning. Although recent studies in an experimental laboratory setting show that error instructions focused at constructive error handling, yield both enhanced control and learning (Van Dyck, 2009), this finding does not necessarily translate to the field. In organizations, error consequences are more real and invasive than they could ever be in the artificial setting of the laboratory.

Thus, it needs to be investigated in which organizational settings constructive error handling yields control, and in which learning. Which organizational settings require control, which require learning. Whether control explains performance enhancements in some, and learning in others. Sitkin et al. (1994) propose uncertainty as the contingency factor determining the desired dominance of either control or learning. Uncertainty is defined as nonroutineness and/or instability (p.538); rates of environmental change (Lawrence & Lorsch, 1967); task variability (Perrow, 1967), summarized by Sitkin and colleagues as "incomplete information concerning attributes, causes or effects of the phenomenon of interest." (p.539). They argue that control is best pursued under low uncertainty, while learning is most appropriate in under high uncertainty.

The translation of Total Quality principles to the domain of errors requires additional incorporation of risk as a contingency factor. Although the concepts uncertainty and risk are related, and at times used interchangeably, risk differs, in that it specifically relates to possibility and likelihood of severe adverse consequences (Chicken & Posner, 1998). What differentiates low and high risk environments is not the severity of errors committed. The exact same error can occur, but may, depending on risk imposed by the environment, bear such different consequences that a layperson would likely classify identical errors as either insignificant or huge. This differentiation is illustrated in the following example:

Turning a valve in the wrong direction may, when adjusting one's heating system at home, not even be considered worth mentioning. Consider the same error when an esteemed mountaineer awaits ascending climbers before he himself can descend from Mount Everest summit: "Harris, who'd left the summit shortly after I did, soon pulled up behind me. Wanting to conserve whatever oxygen remained in my tank, I asked him to reach inside my backpack and turn off the valve of my regulator, which he did. For the next few minutes I felt surprisingly good. My head cleared. I actually seemed less tired than I had with the gas turned on. Then, abruptly, I sensed that I was suffocating. My vision dimmed and my head began to spin. I was on the brink of losing consciousness. Instead of turning my oxygen off, Harris […] had mistakenly cranked the valve open to full flow, draining the tank." (Krakauer, 1997, p. 8).

Analogue to Sitkin et al.'s (1994) line of reasoning on uncertainty, risk poses a contingency factor for preferred dominance of control or learning when error handling is concerned. Control is most important in high risk environments, while low risk environments allow dominance of learning.

Hypothesis 1: There is more emphasis on control of errors consequences in a low uncertainty, high risk setting than in a high uncertainty, low risk setting.

Hypothesis 2: There is more emphasis on learning from errors in a high uncertainty, low risk setting than in a low uncertainty, high risk setting.

From the example of the valve turned the wrong way follows that a particular error per se can not be typified as insignificant or severe. Error consequences obviously can. That there is no such thing as a severe error, does not imply that any one error is similar to the next. Based on the work of Rasmussen (1982), Norman (1981) and Reason (1990) various error taxonomies were developed (e.g., Reinach & Viale, 2006; Stanton & Salmon, 2009; Zapf, Brodbeck, Frese, Peters & Prümper, 1992) that offer a basis for the distinction of error types.

Most error taxonomies differentiate errors based on "cognitive origins" (Reason, 1990, p. 53), i.e. level of regulation associated with the action in which the error occurred. Rasmussen (1982; Rasmussen & Jensen, 1974) distinguishes knowledge-based (high level of regulation), rule-based, and skill-based (low level of regulation) errors. Reason (1990) builds his generic error modeling system on Rasmussen as he differentiates between mistakes and slips and lapses. Mistakes fall into two categories: knowledge-based mistakes and rule-based mistakes. While mistakes involve high and medium levels of regulation, slips and lapses both involve the lower, skill-based level of regulation.

Reason argues that slips and lapses occur in execution or storage phases of action, while mistakes more often occur in planning. This introduces a confound of level of regulation and action phase in error typification. The taxonomy of Zapf and colleagues (1992) differentiates errors according to level of regulation and action phase orthogonally, thereby offering a more sound basis for error research.
The taxonomy of Zapf *et al*. (1992) thus combines level of regulation with phases in the action process. Three levels of regulation are distinguished: Intellectual level (highest), level of flexible action patterns (medium), and sensory-motor level (lowest). Also, three phases in the action process are distinguished: Planning, execution and feedback. The combination of levels of regulation and action phases yields seven distinct error types: At both the intellectual level of regulation and the level of flexible action patterns, errors in planning, execution and feedback are distinguished. This distinction is not made at the sensory-motor level, as actions on this level are so atomized that differentiation between phases in the action process is not possible. In addition to these seven error types, so-called knowledge errors are distinguished. Knowledge errors relate to neither action phase nor level of regulation per se. Rather, they entail errors that are, solely, due to lack of knowledge of the system one is working in.
With regard to the contingency factors proposed, uncertainty would be the most crucial one in research on error types. In environments high on uncertainty, actions at higher levels of regulation should be more common, as the environment holds too many unknowns for automation. Under high uncertainty, more errors on higher levels of regulation are therefore expected than in environments low on uncertainty. As low uncertainty environments are, in contrast, relatively stable, they allow working with standard procedures and protocols. This implies that the "the wheel has been invented" and actions typically take place at lower levels of regulation. Under high uncertainty, more errors on higher levels of regulation are therefore expected than in environments low on uncertainty.

Hypothesis 3a: More errors at a high level of regulation than errors at a low level of regulation are expected in a high uncertainty setting.
Hypothesis 3b: More errors at a low level of regulation than errors at a high level of regulation are expected in a low uncertainty setting.

With regard to action phase, predictions are harder to make. One could argue that under high uncertainty, planning is the most crucial, and challenging action phase, and therefore planning errors are more likely than are execution and feedback errors. Yet, the execution of planned action may well be just as challenging, as is accurate feedback interpretation in a setting that holds many unknowns. In the same vein, in low uncertainty settings, standard procedures and protocols take over the role of high level planning. But this does not necessarily mean that planning is not just as crucial and error prone as execution and feedback. Planning errors would occur if an inappropriate procedure is chosen. There is no reason to assume that that is less likely than the occurrence of errors in execution or feedback.
To summarize, control of error consequences should be higher in a low uncertainty, high risk setting than in a high uncertainty, low risk setting (Hypothesis 1). Conversely, learning from errors should be higher in a high uncertainty, low risk setting than in a low uncertainty, high risk setting (Hypothesis 2). More high regulation level errors are expected in the high uncertainty setting (Hypotheses 3a). Conversely, more low regulation level errors are expected in the low uncertainty setting (Hypotheses 3b). To test hypotheses, extensive qualitative information on recent and specific error occurrences (cf. critical incidents; Flanagan, 1954) is gathered after the error occurred as well as a few weeks later. A high uncertainty, low risk setting and a low uncertainty, high risk setting are consulted.

Methods

Sample. Cooperation was attained from nurses of an emergency unit of a middle-sized hospital and employees from a highly innovative IT company. These two work environments align with the contingency factors uncertainty and risk. Although it may seem counterintuitive that an emergency unit poses low uncertainty, it actually does.
Although dealing with great variations in medical problems to be attended, courses of action are under protocol to a very high degree. This is especially true for the tasks nurses tend to (as opposed to for example diagnosis by medical doctors) who posed as respondents in the current study. Further, peak days (e.g., weekends) and periods (e.g., more fire work burn victims around New Year's Eve) can to a large degree be predicted and logistically prepared for (U. F. Hiddema, general director hospital (not hospital in current study), personal communication, February 2, 2005). If, however, errors occur in an emergency unit, there is always possibility of severe adverse consequences, such as, in the most extreme case, death of a patient. The nurses in the emergency unit are thus working in a low uncertainty, high risk setting.
Employees in the participating IT company deal with creative work, an emphasis on social processes and negotiation with clients. Demands of clients are diverse as well as ever changing, as are the systems used. If problems arise, and they often do, solutions have to be invented on the spot. Experimentation is common. If errors occur, they typically do not pose a threat in terms of severity of consequences. Employees of the IT company thus work in a high uncertainty, low risk setting (see also Eisenhardt, 1993).
Thirty-nine employees (25 from IT company, 14 from emergency unit) expressed an initial willingness to participate. In all, 30 respondents (21 men, 9 women) described one or more error occurrences. This resulted in a total of 78 incident descriptions (T_1), of which 59 were from the IT company (36 at T_2) and 19 from the emergency unit (10 at T_2). Follow-up measurement three weeks later (T_2) were thus

obtained for 46 of the 78 initial errors. *Procedure and measures.* Respondents received a questionnaire (T_1) regarding a recent error, with a follow-up measurement three weeks later (T_2). These questionnaires contained a combination of open-end questions and closed Likert items (for details see below).

First, respondents were asked to describe an error that had occurred in the past two weeks (open-end). Subsequent questions in the Error Tracking Instrument (ETI) were specifically aimed at disclosure of what had happened after error occurrence. That is, respondents were asked to describe when the error was discovered (open-end), when it had originated (open-end), and what the consequences exactly entailed (open-end). Respondents were then asked to rate the severity of these consequences (1=not severe at all to 5=very severe, as well as open-end), and to indicate whether consequences could have easily been either more or less severe (Why? Under what circumstances? open-end).

Respondents were asked to indicate whether the error had been corrected and if so, how (open-end), and whether this concerned trouble shooting or a more long-term solution (open-end). Two Likert items measured the emotional experience upon error discovery. That is, whether respondents experienced strain and embarrassment (1=not at all; 5=to a high degree, for both questions).

The next segment of the ETI dealt with communication and reactions in the workplace. That is, respondents were asked to indicate whether they had informed their supervisor and colleagues, and why (not) (open-end). It was asked how the supervisor and colleagues reacted (1=very angry; 5=very understanding, for both questions), whether and why the error had (not) been further discussed within the work team (open-end), and whether the error's cause had become clear to everyone (open-end).

Three weeks later (T_2) respondents received a second ETI questionnaire, inviting them to describe another error occurrence. With respect to the description of this most recent error, all measures were identical to those at T_1. Most important though, is that at T_2, the ETI inquired again about the error described at T_1: It was asked whether the error (or a similar one) described at T_1 had reoccurred in the three weeks between T_1 and T_2 (no or yes), whether improvements aimed at prevention of this type of error had been implemented (Likert item (1=not at all; 5=to a high degree), with elaboration asked in open-end question), and whether the error had led to new insights and ideas (Likert item (1=not at all; 5=to a high degree), with elaboration asked in open-end question).

Within the IT company, the ETI was distributed and returned via e-mail. In order to ensure anonymity, respondents were informed about the possibility of acquiring a free hotmail account using an alias. Within the emergency unit, a paper and pencil version along with postage free return envelopes was distributed, as e-mail use was not very common. All respondents were asked to put a code or nickname on completed questionnaires, so that T_1 and T_2 questionnaires could be linked.

Coding of qualitative material

Error handling, control and learning. For the open-end questions, Rater 1 developed a coding scheme based on five randomly drawn questionnaires (see below for details). Rater 1 then trained a second rater on five more randomly drawn questionnaires. Where necessary, the coding scheme was adjusted. The two raters then independently rated all questionnaires. Cohen's kappa's range from .80 to 1.00 (for details see below). If qualitative material had been coded differently by Raters 1 and 2, a mean score was computed and used for further analyses.

At T_1, several variables --Communication, Clarity cause, Correction, Detection time, Strain, Empathy of supervisor, and Empathy of colleagues-- relate to Error handling. Codes for Communication range from 1 (e.g., “I have not discussed this error with anyone.”) to 5 (“We thoroughly discussed it in order to handle matters in the best possible way.”; kappa = .91). Codes for Clarity cause range from 1 (e.g., “We did not analyze it. It hasn’t become clear what happened.”) to 3 (e.g., “Yes, boundaries are clear now.”; kappa = .89). Codes for Correction range from 1 (e.g., “The error was not corrected, maybe it will go better next time.”) to 3 (e.g., “Yes, we corrected through alternations in the system.”; kappa = .97). Codes for Detection time range from 1 (low detection time) to 3 (high detection time; kappa = .80), and imply the difference between error occurrence and detection. Strain and Empathy variables were measured with closed Likert items.

Control was operationalized by Severity of error consequences and Containment of consequences at T_1, and Error reoccurrence at T_2. Codes for Severity of error consequences range from 1 (e.g., “There were hardly any consequences”; “The patient just had to wait a bit longer.”) to 5 (e.g., “Serious dispute with client”; “Patient got into shock”; kappa = .93). Scores on Containment of consequences were based on the difference of the actual consequences, and what the consequences could have been. Scores range from 1 (e.g., “No, the consequences could not have been more serious”) to 3 (e.g., “Consequences could certainly have been much more serious, if the error had been detected later”; kappa = .82). Error reoccurrence at T_2 was measured by a dichotomous (no/yes) scale.

Learning was operationalized by whether correction at T_1 entailed a Long term solution or merely trouble shooting, as well as the degree of Improvements and New ideas at T_2. Codes on long-term solution (T_1) ranged from 1 (trouble shooting only) to 3 (long term solution and improvement of processes; kappa = 1.00). Scores for Improvements at T_2 ranged from 1 to 5. These scores were based on a mean score of degree of improvements indicated by the respondent (“Have measures been taken to ensure that the same error can not reappear?” Likert scale, 1 = not at all, 5 = to a large degree), and scores assigned by the raters based on the open-end elaboration on this topic (kappa = .88).

Similarly, scores for New ideas at T2 ranged from 1 to 5. Again, scores were based on a mean score of degree of new ideas indicated by the respondent (“Has the mistake you previously described yielded new insights and ideas?” Likert scale, 1 = not at all, 5 = to a large degree), and scores assigned by the raters based on the open-end elaboration on this topic (kappa = .97).

Type of error. Errors described by the respondents were coded on both level of regulation and action phase, using Zapf *et al.'s* definitions (1992). Two raters, not the same as the raters coding above described error handling, control and learning, coded error types. With regard to the level of regulation, three functional (intellectual level, flexible action pattern, and sensory-motor level) and two miscellaneous categories (knowledge error (n = 3), and not categorizable due to lack of information (n = 15)) were used. An example of an error at the intellectual level of regulation is "For checking the blood levels of trauma patients, blood is drawn upon arrival as well as one or two hours later. In my interpretation of blood levels of the second draw, I did not consider the fact that blood was thin because the patient had been given an I.V.-drip." An example of an error at the level of flexible action patterns is "Although it had been agreed that the client would not be billed for a certain part of the project, an invoice accidentally went out to the client anyway." An example of a sensory-motor level error is "I ticked the wrong box on the lab-form." Cohen's kappa between two independent raters was .93.

With regard to the action phase, three functional (planning, execution, and feedback) and three miscellaneous categories (sensory-motor level (n = 3) -recall that here, action phases cannot be distinguished-, knowledge error (n = 3), and not categorizable due to lack of information (n = 15)) were used. An example of a planning error is "In the description of a specification for the development of new programming the wrong set of standards was used." An example of an error in execution is "I forgot to go to a meeting. It was scheduled in my calendar, but I just forgot to check until much later." An example of an error scored in the feedback phase is "We overlooked the true cause of a problem in the programming." Cohen's kappa between the two independent raters was .81.

As mentioned, of the 78 error descriptions, 15 unfortunately could not be used due to limited information provided by the respondents. An example of an unclassifiable error was described as follows by the respondent: "Patient was treated by [the nurse] without consultation of the physician or intern." From such a description it can not be inferred whether the nurse forgot to check with a physician (e.g., due to chaotic situation, time pressure), or whether s/he thought it was unnecessary to check, or alternatively, whether s/he purposely adhered from checking (in which case it would be an violation rather than an error). Thus, the incident can not be categorized on either action phase or level of regulation.

In all, intellectual and flexible action pattern levels of regulation, and planning and post-planning action phases are included in the analyses. In total, 32 incidents concerned the intellectual level, 25 the flexible action pattern level, and 3 the sensory-motor level. As the sensory-motor level held too low an amount of incidents, this category was excluded from analyses. With regard to action phase, 34 incidents were classified as planning errors, 18 incidents were classified as errors in execution, and 6 incidents were classified as errors in feedback interpretation. As the category planning is relatively large, and feedback small, and because the theoretical distinction between errors in planning and in the follow up after planning is most important, it was decided to combine monitor and feedback categories. Thus, the categories planning and post-planning errors were included in the analyses. The theoretically distinct category knowledge errors, only comprises three incidents. This category was excluded from analyses. Just to give an illustration of the content of this category, one example is given; "In a meeting with the management team of the client company, I brought up the topic of [a change in the programming strategy]. Reactions were odd, and I immediately realized that I probably never should have brought up the topic, as the client clearly had not been informed yet."

Results

A great variation of errors and their handling was reported. These include: Overlooking a lay-out error in an expensive advertisement; A highly confidential concept document for restructuring of the organization that was inadvertently sent to several colleagues; The sales department selling a service for which there was no knowledge of implementation nor capacity to support it; Erroneous billing of hours to a client; Installing an excellent, but for this client, totally use-

Table 1: Illustrations of incidents described.

Incident 1, Emergency unit: Upon the patient's arrival there was a wrong assessment, which caused the illness to deteriorate. The patient got into a shock. The error was discovered and corrected three hours later. If it had been detected just a bit later, the patient would have died. The supervisor was not informed, but a colleague was. Colleagues reacted uninterested. The error was not further discussed within the team, because people feared for their position. At the measurement three weeks later, the respondent reported that no measures had been undertaken since, nor had new insights emerged. The error had not reoccurred in the weeks after its first occurrence.
Incident 2, IT company: The respondent and colleagues had taken up a new project for an important client. There was a verbal agreement, but the client had not signed a contract yet. Due to financial difficulties, management of the client company was unwilling to sign, or to pay for the work that had already been done. There was a strong (legal) case to make the client pay, but playing "hardball" might be undesirable as it would probably result in losing this client altogether. The problem was recognized when the project was in its second week, but nothing was done for four more weeks. For the IT company, this problem meant a loss of income, for the employees it meant not attaining a bonus. Without laying blame, the problem was further discussed with all people involved. This resulted in a decision to cut the losses, while making sure that this problem could not reoccur. The group concluded that a flawed communication process was at the root of the problem. Three weeks later, the respondent reported that the mistake had yielded a lot of new insights and that many improvements had been implemented since. Contract managers, who served as a central contact for clients were to be appointed and check ups had been implemented for contract statuses. Further, the sales process was improved.

less application; Missing a work related exam due to wrong registration; A patient falling of a hospital trolley; A blood sample mix up; Using an expired drug. For illustration purposes, more elaborate descriptions of two incidents are given in Table 1. The first segment describes an incident where the death of a patient was averted in the nick of time. The incident was not discussed openly, nor did it lead to new insights or the implementation of improvements. The second segment describes an incident that has not been handled as quickly or efficiently as it possibly could have, but does show learning from errors and implementation of improvements.

in the two participating organizations are considered (see Table 3). With regard to level of regulation, in the emergency unit one-quarter of the described errors (n = 3) are at the higher Intellectual level, three-quarters (n = 9) are at the lower Flexible action patterns level. The IT company shows a reversed pattern. Here, two-thirds (n = 29) are at the Intellectual level, one-third (n = 16) is at the Flexible action patterns level. To test for an effect of setting on level of regulation related error types Fisher's Exact Test was used. As the test yields significance (LR-χ^2 (1) = 6.09, p = .04, 2-sided test), it can be concluded that setting affects error type. Hypothesis 3 is thus supported.

Table 2: Kappas, Means, Standard Deviations and Correlations for Error Handling, Control and Learning Variables.

		Type	N	Scale	Kappa	M	SD	1	2	3
	T1:									
1.	Communication	error handling	77	1-5	.91	3.71	1.49			
2.	Clarity Cause	error handling	77	1-3	.89	2.34	.68	.60**		
3.	Correction	error handling	78	1-3	.97	2.42	.83	-.18	-.05	
4.	Detection time	error handling	78	1-3	.80	2.37	.46	-.04	-.05	-.09
5.	Strain	error handling	78	1-5	n.a.	3.29	1.19	.10	-.09	-.24*
6.	Empathy supervisor	error handling	41	1-5	n.a.	3.56	.98	-.06	-.10	.03
7.	Empathy colleagues	error handling	65	1-5	n.a.	2.87	.93	-.11	-.21#	-.10
8.	Severity consequences	control	77	1-5	.93	2.75	1.03	.22#	.21#	-.29*
9.	Containment consequences	control	75	1-3	.82	2.01	.83	.10	.06	.30**
10.	Long term solution	learning	72	1-3	1.00	1.87	.91	.46**	.18	-.29*
	T2:									
11.	Error reoccurrence	control	43	1-2	n.a	1.14	.35	.06	.03	.06
12.	Improvements	learning	46	1-5	.88	2.80	1.41	.35*	.29#	-.17
13.	New ideas	learning	45	1-5	.97	2.52	1.30	.36*	.27#	-.29#

Table 2 shows correlations between error handling, control and learning variables at both T_1 and T_2. Results show that Correction is positively related to Control of error consequences, while Communication, and to a lesser degree Clarity of the error's cause, predict learning at both T_1 and T_2: The higher the degree of error Correction, the better the negative consequences were controlled, in terms of both Severity of consequences (r = -.29), and Containment of consequences (r = .30). Communication is associated with Long-term solutions, rather than mere trouble shooting at T_1 (r = .46). In addition, Communication predicts the implementation of Improvements (r = .35) as well as the amount of Ideas and insights (r = .36) generated in the weeks following the first measurement (T_2). Detection time, strain and empathy do not predict either control or learning.
Control of error consequences was higher (F (1, 76) = 5.34, p = .02 for severity of consequences; F (1, 74) = 3.49, p = .07 for containment of consequences) in the emergency unit (M = 2.29 for severity; M = 2.32 for containment) than in the IT company (M = 2.90 for severity; M = 1.91 for containment). Hypothesis 1 was thus supported. Learning was higher in the IT company than in the emergency unit (F (1, 71) = 4.38, p = .04), with more Long-term solutions at T_1 in the former (M = 2.00) than in the latter (M = 1.50). No effects on T_2 variables were found. Hypothesis 2 was thus partially supported.

It was then tested whether outcomes are different for various error types. For this purpose, first, the types of errors

With regard to action phase, in the emergency unit one-third of the described errors (n = 4) is in Planning, two-thirds (n = 8) in Post-planning phases. Again, the IT company shows a reversed pattern. Here, two-thirds (n = 29) are in Planning, one-third (n = 16) in Post-planning phases. Fisher's Exact Test does, however, not reach significance (LR-χ^2 (1) = 3.74, p = .11, 2-sided test).

To test whether different error types yield differences in error handling, control and learning two (level of regulation: Intellectual vs. Flexible action patterns) by two (action phase: Planning vs. Post-planning) ANOVAs were conducted.[1] The ANOVAs on both Communication and Clarity of error cause yielded interaction effects with higher Communication for Planning errors at the Intellectual level (M = 4.15) and Post-planning errors at the level of Flexible action patterns (M = 4.13) than Post-planning errors at the Intellectual level (M = 2.81) and Planning errors at the level of Flexible action patterns (M = 2.80; F(1, 55)= 10.87, p = .002). Similarly, Clarity of the error's cause was higher for Planning errors at the Intellectual level (M = 2.67) and Post-planning errors at the level of Flexible action patterns (M = 2.50) than Post-planning errors at the Intellectual level (M = 1.89) and Planning errors at the level of Flexible action patterns (M = 2.00; F(1, 56)= 13.17, p = .001). A marginally significant main effect of level of regulation on Correction was found (F(1, 56)= 2.62, p = .053), with more Correction for errors at the Flexible action patterns level (M = 2.64) than those at the Intellectual level (M = 2.25). A main effect of action phase on Detection time was

Table 2 (continued)

		Type	4	5	6	7	8	9	10	11	12
	T1:										
1.	Communication	error handling									
2.	Clarity Cause	error handling									
3.	Correction	error handling									
4.	Detection time	error handling									
5.	Strain	error handling	-.13								
6.	Empathy supervisor	error handling	-.04	-.20							
7.	Empathy colleagues	error handling	-.10	-.10	.31#						
8.	Severity consequences	control	.18	.27*	-.10	-.22#					
9.	Containment consequences	control	-.09	.04	-.15	.08	.00				
10.	Long term solution	learning	.08	-.02	.07	.14	.16	.05			
	T2:										
11.	Error reoccurrence	control	.12	-.13	-.26	-.04	-.05	.01	-.01		
12.	Improvements	learning	.06	-.01	.10	-.10	.02	-.25	.28#	-.19	
13.	New ideas	learning	-.06	.14	-.03	.22	-.06	-.02	.22	-.25	.54**

Note. N (i.e. number of incidents) is 78 at T_1 and 46 at T_2. As not all errors were reported to the supervisor or colleagues there are less cases on the empathy variables. n.a.: not applicable; # $p < .10$; * $p < .05$; ** $p < .01$, all tests are two-tailed.

Table 3: Distribution of reported error incidents across setting and error types.

		Action phase		
Setting:	Level of regulation	Planning	Post-planning	Total
Emergency unit	Intellectual	-	3	3
	Flexible action patterns	4	5	9
Total		4	8	
IT company	Intellectual	23	6	29
	Flexible action patterns	6	10	16
Total		29	16	

found ($F(1, 56)= 6.16$, $p = .02$), with higher Detection time for Post-planning ($M = 2.63$) than for Planning errors ($M = 2.27$). No main or interaction effects were found for Strain or Empathy variables.

With regard to control of error consequences, a main effect of level of regulation on Severity of consequences was found ($F(1, 56)= 5.30$, $p = .03$), with more severe consequences for errors at the Intellectual level ($M = 3.05$), than errors at the level of Flexible action patterns ($M = 2.52$). No effects on Error reoccurrence at T_2 were found.

For T_2 learning variables, marginally significant main effects of level of regulation were found: In the weeks after the error had been reported, errors at the intellectual level yielded more Improvements ($M = 3.33$) and New Ideas ($M = 2.81$), than did errors at the level of Flexible action patterns ($M = 2.38$, $F(1, 33)= 2.94$, $p = .097$; and $M = 1.96$, $F(1, 32)= 3.66$, $p =.066$ respectively). No effects on Long-term solutions (T_1) were found.

Discussion

In line with earlier research, error handling was related to both control and learning. Results show that control and learning are differentially predicted by error handling: Control of error consequences is positively affected by correction. Communication predicts learning in the following weeks.

The low uncertainty, high risk setting was higher on control of negative error consequences (Hypothesis 1), while the high uncertainty, low risk setting was higher on learning from errors (Hypothesis 2). The error tracking study thus offers a first indication that control and learning could indeed be the important, yet differentially requisite mechanisms that link error culture and organizational performance.

Results further show that the two sites differ in error types. More lower level than higher level of regulation errors were found in the low uncertainty, high risk setting. Conversely, more higher regulation level than lower regulation level errors were reported in the high uncertainty, low risk setting (Hypothesis 3). No effect of setting on errors in planning versus post-planning phases was found.

The two settings studied thus show, in concordance with hypotheses, differences in both error types and control and learning from them. This poses the question whether environmental demands influence control and learning, whether error types do, or both. I would argue for the latter, that is, control and learning are (and should be!) affected by environmental demands, with demands for control under low uncertainty and high risk, and learning under high uncertainty and low risk. In addition, intellectual level errors are more likely in high uncertainty settings. In such settings, characterized by instability and lack of routines (Sitkin et al., 1994), higher level processing is as crucial as it is tricky. Higher level errors would seem most likely to provide insights and chances to learn, as they challenge the appropriateness of courses of action (cf. learning in error management training; Dormann & Frese, 1994; Frese, 1995). Indeed, results of the current study show that errors at a high level of regulation yield most ideas and improvements. Further research into this issue is, however, necessary. In future research a full uncertainty/risk factorial model, including low uncertainty/low risk settings, high uncertainty/low risk settings, low uncertainty/high risk settings, and high uncertainty/high risk settings, could shed a more profound light on the relations between setting, error types and con-

trol and learning.
Differences in error types may offer further insights in the roles of error handling, control and learning. Flexible action pattern post-planning errors, and intellectual level planning errors yielded most communication and clarity about the origins of the error. A possible interpretation of this finding is that these errors relate to the types of actions that are most salient. That is, for low uncertainty, high risk settings emphasis is on control, and lower level, post-planning errors may represent precisely the type of error that offers room for improvements of procedure, hence legitimizing communication and analysis. To illustrate this point, consider the incident where a patient fell of a hospital trolley. The error occurred because nurses had forgotten about the patient, as at the same time another, severely injured patient was admitted. It is precisely this type of --in principle simple—error that may easily be prevented in the future (thereby enhancing control), by procedures. Following the same line of reasoning, planning errors on a high level of regulation may offer most opportunities for learning in high uncertainty, low risk settings: A respondent from the IT company reported an incident where the client continuously came up with additional objectives to the project. The IT project management did not communicate any limits regarding time or budget. No differentiation was made between so-called 'must-haves', 'must-have-but-later', and 'nice-to-haves'. The project management was poorly anticipating changing demands, and lost control both in terms of time and budget. As a result the budget was largely overdrawn. Thus, errors in crucial domains for that setting, may offer enhanced opportunities in terms of potential gain in either control or learning, and may therefore be considered important to talk about and analyze.
It remains to be further investigated whether control and learning differentially act as true mediating factors in error handling-performance relationships across settings. For such a test, larger samples of error incidents are required, and outcome measures should be included. In larger samples, differences in both direct and mediating relations between error handling, control, learning and outcome variables could be assessed across settings. It could then be tested whether all companies benefit from a constructive error culture, but do so in different ways.
With ample issues to be addressed in future research, the current study has shed a first light on contingencies for control of consequences and learning from error.
Knowledge about such contingencies may help organizations optimize their approach to error. In addition, taking environmental demands into consideration may foster awareness of likely error types, and subsequent desired error handling. Research in a related area (Wall, Jackson & Davids, 1992) showed that the reason why operators produced performance gains after the introduction of a new payment system was that they optimized fault management. These issues become all the more important in case of a shift in environmental or task demands. This would be the case in organizational change, adaptation of innovation, learning new approaches, and boundary lines of routine approaches. A study by Edmondson and colleagues (Edmondson, Bohmer & Pisano, 2001) nicely illustrates how some teams have extreme difficulties adapting a new, highly innovative methodology for cardiac surgery, while other teams adapt well: What had changed was more than the technical approach. The new methodology required dramatic changes in group roles. Shared responsibility and communication about errors –hard to embrace for some surgeons—were prerequisites for success. While all operating teams had excellent records on the previously used technology, the changes in task demands in the new approach posed a serious problem for some teams.
Furthermore, environmental or task demands may still vary even if the organization is not going through a period of change. Within most, if not all organizations, there are various demands to be dealt with. Departments differ, compare for example an accountancy and R&D department within the same company. Where task characteristics in the first are associated with low uncertainty, and demands imply control, high uncertainty and a focus on learning would apply to the latter. Similarly, within departments, within employees' task descriptions even, contingencies and demands may vary. One of the findings in HROs is that members of these organizations are particularly capable in switching between control focused and learning focused roles. Pool (1997) describes how on an aircraft carrier, employing military soldiers, the general climate is one of strict hierarchy, structure, and standardization. During take-off and landings of fighter airplanes, however, the team has to, among other things, base decisions about break-strappings on a large number of factors such as weight (based on amount of kerosene left in the tank) under extreme time pressure. In this particular setting, it is understood among all that rank is no issue when there is even the slightest hint of an error. Hierarchy is temporarily lacking and speaking up is the desirable course of action.
Only when contingencies in error handling, error types, control and learning are fully understood, can managers prepare for demands posed. The current study offers a first step towards attaining that goal.

Note:
[1]. Due to the combination of missing values mainly on Empathy supervisor (as this measure is not applicable if the supervisor has not been informed), and data loss due to the fifteen uncategorizable error incidents, MANOVA is not a good option. Similarly, due to data loss at T2, ANOVAs rather than MANOVAs are conducted for control and learning variables.

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