Taxonomic Guidance for Remedial Actions

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Abstract

Objectives: This project developed a taxonomy to provide guidance in selecting remedial actions to address problems uncovered during root cause analyses of events in a medical setting. **Methods**: The taxonomy incorporates the work of Norman, Rasmussen, van der Schaaf, and others to characterize and classify the failures that lead to an event. The classifications are then linked to likely efficacious actions, and possible solutions are ranked by the likelihood that they would be effective in addressing the identified problems. **Results**: The project developed a taxonomy that suggests types of remedial actions likely to prove efficacious, as well as those that usually fail to have any effect. **Conclusion**: This system could assist when addressing safety problems. The system presented here still requires testing and refinement.

Introduction

Event analysis, properly performed, has proven to be an effective tool for identifying and addressing accident-prone activities and situations in several industrial settings. The Joint Commission for Accreditation of Healthcare Organizations requires deliverers of health care to perform event analysis when dealing with serious events. However, after performing a root cause analysis, the question often remains of how to use the results. It does little good to identify the causes of events without guidance on how to address them. Far too often the responses consist of new rules that prevent that particular problem from arising again, but fail to address the underlying problems or establish actions that could prevent a larger class of accidents. This project developed a relationship between classifications of failures that lead to events and possible remedial actions to provide guidance to persons performing event analysis.

A taxonomy is simply a classification or ordering into groups or categories. The key in the definition is ordering or having an organization behind the categories, rather than simply a listing. In the context of event analysis, taxonomy provides a structure to help the investigator assign categories to the actions that led to the event. The goal of such categorization is twofold:

1. To look for commonalities that would not be evident from a list of the different erroneous actions. Consider for example two events at a given facility. In one, the nurse failed to respond when a patient stopped breathing because the alarm on the monitor malfunctioned. In the second event, a patient failed to receive a medication because the printer at the nursing unit broke and the nurse never saw orders for delivery. The facility had a problem with preventive maintenance of its

equipment, but looking at each event alone may only have identified the individual pieces of equipment as needing service.

2. To provide guidance for selecting remedial actions to address the causes of past events, particularly the latent causes.

Previous taxonometric studies

Taxonomies have been used for assessment of human performance failures since the end of the 19th century. Reason presents a good review of the development of taxonomies for such applications and develops a very comprehensive taxonomy of his own.[1] The work presented in this chapter owes much to four previous taxonomies, namely those of Norman,[2] Rasmussen,[3] van der Schaaf[4] (expanded in vanVuuren et al.[5] and Koppens[6]), and Kapp and Caldwell.[7]

Norman considered the psychological causes for speech errors.[2] The classification system he developed dealt mostly with slips. He groups the slips into three general categories:

1. Those that result from errors in the formation of the intent.
2. Those that result from faulty activation of usually-controlled behavior.
3. Those that result from faulty triggering of a behavior.

While his study concerned speech, Norman acknowledged that the errors also applied to other activities. However, the failure taxonomy only addresses a small part of the range of errors potentially encountered in the arena of all types of actions.

Rasmussen developed models for human actions based on the level of intellectual consciousness required for the work: skill-based, rule-based, or knowledge-based (SRK).[8] Skill-based actions are well learned and practiced, proceeding without much conscious involvement. Activities such as driving a car (much of the time) or recitation of prayers during religious services often form examples of skill-based activities. Rule-based actions begin when faced with decisions about what skills to apply to a situation. In job settings like nuclear power plants, where much of Rasmussen's models evolved, most situations encountered by workers are quite predictable, and the worker receives training to develop the skills required. The first response to an observed situation entails selecting the rule that determines which skills to invoke. Knowledge-based actions only arise for situations that fail to match a rule, and the worker must apply knowledge about the system to determine the actions appropriate for the situation. The types of failure that take place at each level are different, and Rasmussen goes into great detail in discussing such errors, generating a taxonomy to classify them,[3] and even discusses how to use the information in establishing a plan to correct problems.[9] Rasmussen concentrates on the mechanism by which actions fails, without great attention to why the operator failed to perform correctly. He also treats the operator much as an automaton, which in the setting of the power plant may have been quite appropriate. In freewheeling, unstructured medical settings, almost all operators exhibit more freedom of action and have less guidance in selection of rules.

The Eindhoven taxonomy, developed by van der Schaaf[4] and others[5, 6] originated in chemical plants similar to nuclear power plants, and has been refined and applied to medical settings.[5, 6] The Eindhoven taxonomy focuses on the performance-shaping causes of the failure first, and only if no nonuhuman technical or organizational cause is found, resorts to describing the type of human failure that leads to an event. The taxonometric classification falls in one of four levels:

1. Technical problems (machine failures)
2. Organizational problems
3. Human performance failures
4. Patient-related factors

Determining the classification for an event entails following a pathway on a diagram where each category is a box along the pathway. The first box that fits the event establishes the classification for that event. By design, technical problems, the first boxes, are the easiest to fix, and elimination of technical problems would likely prevent future events of similar nature. The second classification, organizational problems, establishes the environment for the failures leading to the event. These organizational problems form the latent causes. Of the organizational failures, those easiest to fix (training, and then protocols) come first. Of the remaining organizational problems, management priorities *may* be fixable (particularly if management has instigated the investigation that lead to the classification), or may not be. Safety culture probably remains a problem without resolution, in which case the investigation should proceed to the human performance failures classification. Human performance failures, the third group, are classified by level according to SRK actions. Under the category of rule-based action failures, there are subpaths for qualifications, verification, coordination (as in communication), intervention, and monitoring. The skill-based errors are defined as “slipping” (fine motor problems) and “tripping” (gross motor problems). It can be argued that the final classification, patient-related factors, should never be scored. The medical staff should be prepared to react to whatever the patient does.

Unlike Rasmussen, Eindhoven views the operators more as independent agents, whose actions are shaped by the environment (which is formed by the technical and organizational factors). The Eindhoven taxonomy has been applied in medical settings for blood bank operations[10] and anesthesiology.[5, 6]

The taxonomy of Kapp and Caldwell bases event classification categories on five functional aspects of actions: detection, interpretation, rule selection *or* planning, and execution.[7] Each of these general categories contains four classifications to describe the cause of failure at that step. Thus, this taxonomy’s classifications combine the stage in the conceptual process where the error occurred with the nature of the cause of the failure. As with the two previously discussed taxonomies, this one determines the classification by following a pathway-type chart. Initially, this taxonomy assumed that the first failure encountered along the pathway determined the classification for the event, but later Kapp and Caldwell came to believe that an event may contain several failures (personal communications, 1998).

The Madison Medical Taxonomy

Following the leads of Norman, Rasmussen, van der Schaaf, and others, we developed a classification system to characterize the nature of the failures that led to an event. This taxonomy addresses failures in health care settings. This new taxonomy does not assume that an event under study begins with an initiating event, but rather recognizes that health care is a continual cycle of patient needs and actions and reactions of caregivers. Because of the chaotic aspects involved in patient care, there is always some experimentation on the part of the caregivers and continual correction to achieve the goal of curing the patients (or otherwise addressing the patients' needs). This differs markedly from controlled, industrial settings where processes usually proceed as planned.

The design for this taxonomy assumes that many factors influence the failure that results in an event. Most often, removing any one of the factors might prevent the event. Therefore identifying as many factors as possible helps guide actions that may prevent future failures from propagating into events. Thus, any given event may be affected by many factors and so may have many taxonometric classifications associated with it. Each classification carries potentially useful information.

This taxonomy begins the classification of failures in an event with the first step notably outside of appropriate action and the corresponding responses to that step. At each new step, we not only focus on where the process went wrong, but also try to identify the underlying motivational mechanism as well as the hardware/software problems, or the organizational and environmental performance-shaping factors that enable the initiating event or the improper responses.

The taxonomy includes four main tiers. The first tier considers what happened. As in Kapp and Caldwell's taxonomy,[7] the second tier focuses on which major component of action failed. The third tier of the taxonomy attempts to find what contributed to the failure. Finally, in the fourth tier the underlying cognitive mechanisms of human malfunction, as well as the detailed categorization of the shaping factors and conditions, are characterized. The fourth tier relates to the third tier as a parent classification. At the third and fourth levels, the taxonomy determines whether the failure should be categorized as a human error or a hardware/software malfunction, and whether there are any enabling factors such as organizational factors or environmental-shaping factors that contributed to the event.

Level 1: What happened?

The first tier looks for the origin of the event. The event may have started because

- An action was taken when no action should have been.
- An action was called for but no action was taken.
- An action was called for but the wrong action was taken.
- An action was called for but failed in the execution.

Level 2: Which major component of the action failed?

Figure 1 shows the second tier of the taxonomy. The three main categories are mistaken action, failure of detection, and failure of reaction. The categories follow the lead of Kapp and Caldwell.[7] A failure of detection can result from

- The absence of an available method (i.e., no protocol or an ineffective protocol) for detecting the problem in the situation.
- The people involved missing the error due to a malfunction of the equipment.
- Failure to perform a detection action.
- Incorrect execution of a detection action.
- Simply missing the detection, even though all actions were executed correctly.

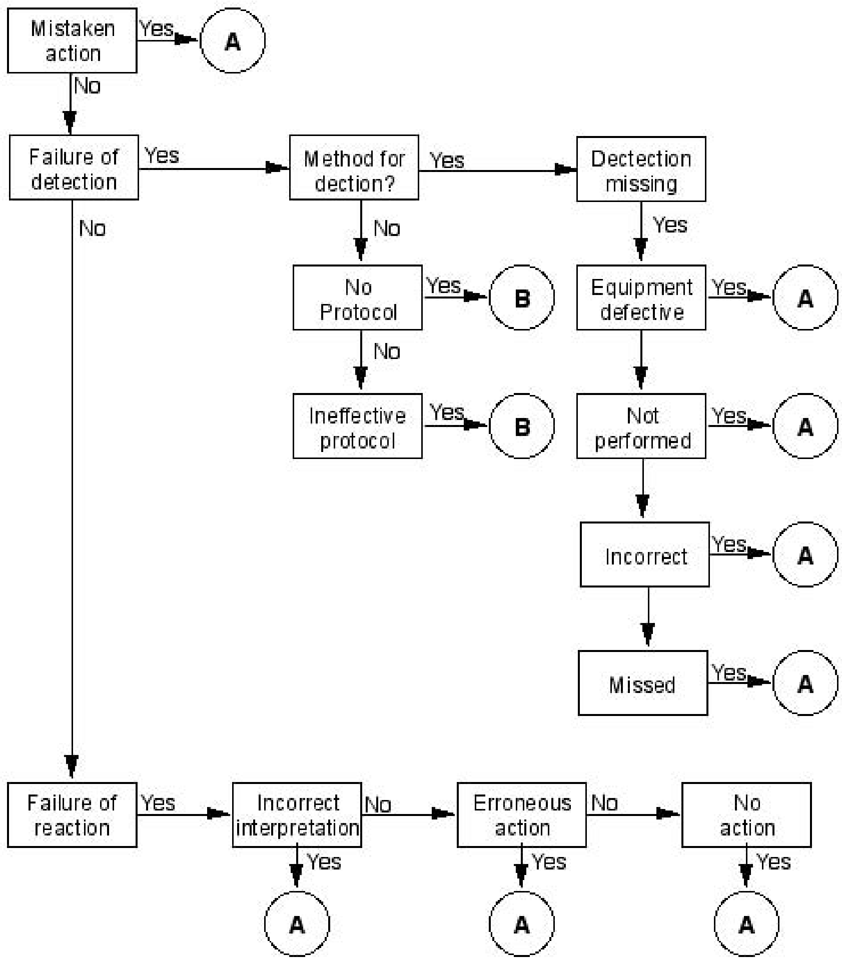
Note that all the categories in this level eventually transfer to the third tier, "What contributed to the failure" subpath. The categories "no protocol" and "ineffective protocol" (for detection) lead to the organizational shaping factors, at the bottom of the third tier categories.

Level 3: What contributed to the failure?

The third tier of the taxonomy is illustrated in Figure 2. In this level, any box to which the path leads must be considered for possible contributions to the failure. A YES answer at the human error or hardware/software boxes leads to the respective pathway and consideration of possible contributions from each box therein. A YES at the human error box also leads, via the circled C, to the human factors sub-subpath in Figure 3. Either a YES or NO at either box still leads to the enabling factors box and consideration of possible contributions from the four topics along the bottom of the figure. The circle with the B inside indicates the entry point from the circle-B points from Figure 1.

For human failures, the path leads to the fourth tier of taxonomy and the human error sub-subpath. The human error subpath in level three draws from the Rasmussen SRK model,[8] the Eindhoven Classification Model Medical Version,[5, 6] and Norman.[2] Slips and tripping are skill-based errors which refer to actions not in accord with the operator's intentions. As in the Eindhoven taxonomy, slips

Figure 1. Madison Medical Taxonomy second tier pathway *



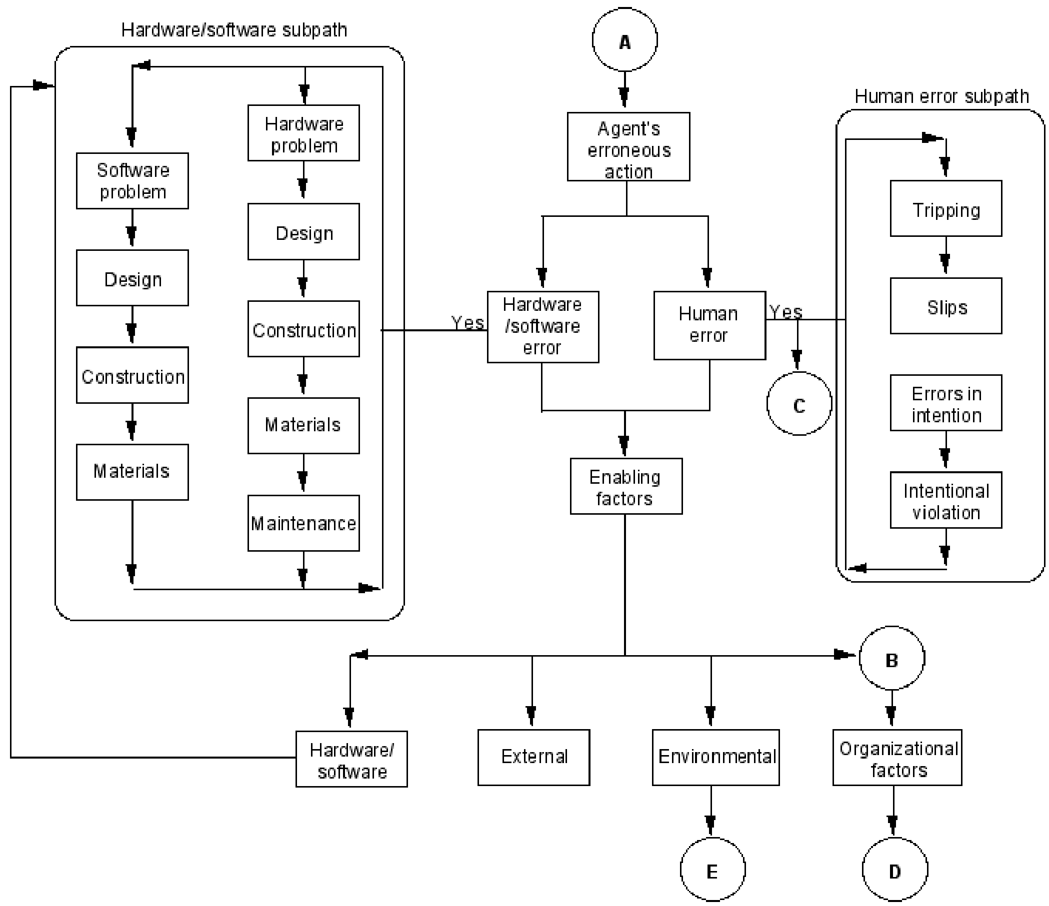
*The lettered circles lead to the third level of the taxonomy.

refer to failures in the performance of fine motor skills, and tripping refers to failures in whole body movement. A mistake is a planning failure that happens when an incorrect intention is formed and the wrong action is executed. These human error categories will be further classified based on their underlying cognitive mechanism in the fourth tier of the taxonomy (Figure 3).

The hardware and software subpaths are also borrowed from the Eindhoven Classification Model Medical Version.[5, 6] A hardware/software failure can be due to a poor design, a good design poorly constructed, or poor maintenance. A material defect (which is not directly related to either poor design or poor construction) may also cause a hardware failure.

The last row of the third tier of the taxonomy (Figure 2) shows the main categories of performance-shaping and situation factors. These categories include factors or conditions that may affect the probability of making an error, but do not directly cause the error. Hardware/software failures seldom actually cause events or untoward outcomes in medicine, but often lead operators to make mistakes. In such situations, they shape the performance of the human operators. For example,

Figure 2. Madison Medical Taxonomy third tier pathway, what contributed to the failure



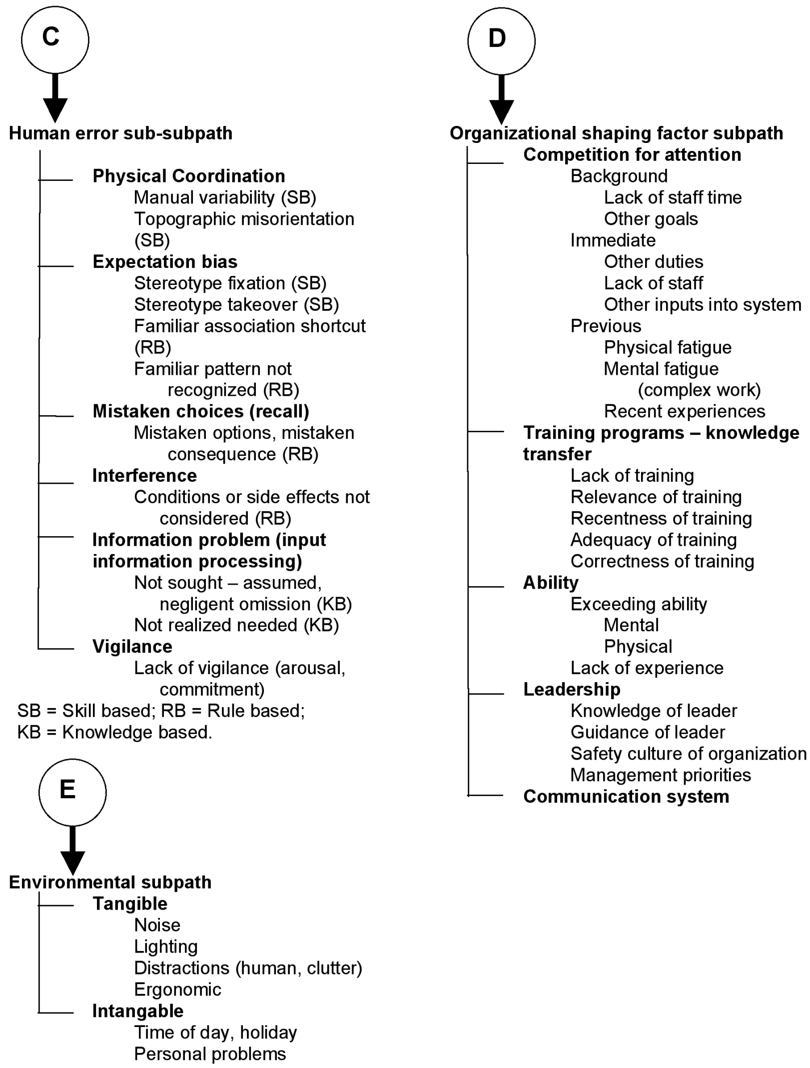
a control panel with a poorly organized layout might increase the chance of hitting a wrong button, but does not mean a wrong button will certainly be hit. Other shaping factors include external factors, environmental factors, and organizational factors. These factors will be further categorized at the fourth tier of the taxonomy.

Level 4: Why did it fail?

In the fourth tier of the taxonomy, we focus on the underlying cognitive mechanism of human malfunction and the factors that influence or interfere with human performance. Figure 3 presents human error, and the organizational and environmental enabling factor classifications. The entry points are the circles that continue the pathway from Figure 2. In each of the paths, all classifications must be considered because multiple causes are likely to be involved.

The human error sub-subpath (human error how/why) is based to a large extent on the SRK approach described in Rasmussen.[3] The terms "skill-based," "rule-based," or "knowledge-based" information processing also refer to the degree of the operators' conscious control of the corresponding activities. A

Figure 3. Madison Medical Taxonomy fourth tier pathway



skill-based error usually happens when a familiar, automatic procedural task is performed. This type of error can occur due to manual variability or inadequate topographic orientation. A skill-based error can also occur when the situation deviates from the normal routine. If the sensory input is so weak that the operator does not respond to the change, the operator makes an error due to stereotype fixation. On the other hand, if the operator realizes and responds to changes but unconsciously executes a more familiar and highly-skilled task instead of the planned task, the error is due to a stereotype takeover.

A rule-based error happens when operators perform tasks approached by pattern matching with a set of internal problem-solving rules. Rule-based errors can be due to a familiar pattern not being recognized (when a situational change is covered by the normal work know-how, but the operator fails to realize this), a familiar association shortcut (responding to familiar cues that form only an incomplete part of available information), or mistaken options (not recalling the rule correctly). Finally, knowledge-based errors happen when a situation is unique and unknown, for which no rules exist and intelligent problem-solving is required. Knowledge-based errors can be due to information problems (information not being sought, information being assumed, or failure to realize information is needed) or inference errors, when conditions or side effects are not fully considered.

Four types of enabling factors are presented in the third tier of the taxonomy. Two of these factors are expanded in the fourth tier (see Figure 3). Organizational factors include knowledge of leader, management priority, communication system, knowledge transfer, and ability. Environmental-shaping factors are classified into three main categories: competition for attention, environment, and others. These main categories can be further divided into subcategories. For example, the environment can be tangible (such as sound, noise, visibility, and lighting) or intangible (such as the end of day or a holiday). While commonly call "performance-shaping factors" in the human performance discipline, this taxonomy uses the term "enabling factors," drawing on the psychological parallel of enabling behavior that assists another person in destructive activities.

Guidance for remedial actions

As noted in the introduction, one of the main goals for working with taxonomy to classify the failures related to an event is to help identify remedial actions to correct deficiencies and prevent repeated events occurring in different procedures. In theory, the remedial action required to address a given failure not only depends on what that failure *was* (such as missing the detection of a situation deviating from normal), but on the reason for the failure. The headings on the columns in Figure 4 list some of the categories of remedial actions. The listing certainly is not exhaustive, and it is hoped that new tools will be developed in the future. The row labels are a sampling of the failure classification in the taxonomy. Each major group of the rows (Which component, What, and Why) follows the tiers of the classifications. An X at the intersection of a column and row indicates that the remedial action tool in that column may be effective in addressing a failure of the type in that row. A blank indicates that the column tool likely would not produce much improvement for the causes of failure given in the row. A question mark denotes uncertainty, either because the failure can have multiple causes that may differ in their responsiveness to a given remedial action, or because the relationship between the action and the cause of the failure requires more research.

The tools, of course, differ in their power to effect changes. Some—such as computer order entry with feedback to the operator about variances from normal patient care—are very strong in preventing errors. Other tools, such as passive signs, while necessary, often effect only small or transient improvements. Table 1 presents a hierarchy of the tools with respect to effectiveness. This hierarchy is similar to that of the Institute for Safe Medical Practices.[11] When selecting tools

Figure 4. Sample of matrix relating failure classification to remedial actions

		Physical tools				Info	Measurement tools					Comput		Knowle		Administrative tools							Equip	
		Interlocks	Alarms	Barriers	Communication devices	Reduce similarity	Check-off forms	Comparison with standards	Increase monitoring	Automate monitoring	Independent review	Computerized verification	Feedback computer order	Training	Experience	Mandatory pauses	Staffing	Establishing protocol	Clarify communication	Better scheduling	(Administrative) priority	External audit	Repair	Establish QC and QA
Which component	Mistake action																						O	O
	Detection - No protocol																	X						
	Detection - Equipment defect																						X	
	Detection - Not performed	X	X				X			X		X		?	?	?								
	Detection - Incorrect				X	X													X					
	Detection - Missed	X	X		X		X		X	X				?	?									
	Reaction - Incorrect interpretation										X	X	X	X	X									
What	Human error - Slips	X	X	X	X	X	X	X	X	X	X	X	X											
	Human error - Blunder	X	X	X	X	X	X	X	X	X	X	X	X											
	Human error - Error in the intention (mistake)	?	?	?							X		?											
	Hardware failure																						X	X
	Software failure																							X
	Enabling factor - Hardware						X												X					
	Enabling factor - Software						X												X					
	Enabling factor - Organizational													?	?		?	?	?	?	X	X		
Why	Hardware - Design																						?	
	Hardware - Material																						X	
	Hardware - Maintenance																						X	X
	Software - Design																						?	
	Topographic misorientation (SB)	X											X											
	Stereotype fixation (SB)	X	X	X	X	X	X	X	X	X	X	X							X					
	Stereotype takeover (SB)	X	X	X		X	X	X	X	X	X	X				X								
	Familiar association shortcut (RB)	X	X	X		X	X			X		?				X								
	Familiar pattern not recognized (RB)				X	X	XX	X		X		X			X	X	?							
	Mistakes alternatives (RB)						X				X	?	X	X	X			X						
	Mistake consequence (RB)						?				X	?	X	X	X			X						
	Forget isolated act (RB)	X	X	X	X		X	?		?	X	X			?									
	Condition or side effect not considered (KB)	X	X	X				X	X		X	X		?	?									
	Lack of vgilance	X	X	X			?		X	X	X	X	X											
	Organizational - Knowledge of leader										X			X	X									
	Organizational - Management priority										X													
	Organizational - Abaility													X	X									
	Competition for attention - Other duties	?	?	?			?			X	X	X	?				X	?			X			

for remediation, those at the top of the list should be tried first, if possible. The problem with following that recommendation, of course, is that the more active and effective tools often require the most resources to implement. (For example, computer order entry programs are very expensive and often have long learning curves and longer acceptance curves.) As with any changes, the effectiveness, and the effects, must be monitored closely and other tools applied if the first produces less than effective correction.

The table lists fixing environmental factors first. While these actions may not address deeper issues, they usually form some of the least expensive and most obvious actions. Often, removing the environmental enabling factors prevents other latent causes from propagating into future events. Since an event often carries multiple classifications, tools that apply to several of the event's classifications should be given increased importance during the selection of remedial actions.

Table 1. The hierarchy for remedial action tools based on decreasing effectiveness*

1. Fix environmental problems Sound control Visual control Neatening Cleaning Isolation Design **2. Forcing functions and constraints** Interlocks Barriers Computer entry with feedback **3. Automation and computerization** Bar codes Computer entry Computer feedback Automatic monitoring **4. Protocols, standards, and information** Check-off forms Establishing protocol/clarifying protocol Alarms Labels/signs Reduce similarities	**5. Independent verification and redundancy** Independent review Redundant measurement Operational checks Comparison with standards Increased monitoring Added status check Acceptance test **6. Rules and policies** External audit Internal audit Priority Establish/clarify communication Staffing Scheduling Mandatory pauses Repair Preventive maintenance Establish/perform quality control/quality assurance **7. Education and information** Training (initial) Experience Instruction

*Note that the environmental list indicates only some factors that need to be corrected, without details on the actions, since the corrective actions are likely to be obvious.

Conclusions

The taxonomy presented in this chapter has taken many of the positive features of previous taxonomies that have proven useful in industrial settings and adapted these features for use in medical practice and health care delivery. The classification of an event takes into account where failures occurred in the overall process, how the failure manifested itself, and the causes of the failure on two levels. Further, a matrix keys possible remedial action tools to the classifications based on the types of actions that would likely prove efficacious. The system ranks the remedial tools according to the probability that they would effect changes necessary to address the causes of the event and prevent future events.

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