

#### **4.4 HUMAN ERROR IDENTIFICATION: DESIGNING FOR THE USERS - MARILYN SUE BOGNER, PH.D.**

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Even though human factors efforts have been directed to reducing the likelihood of human error in a number of domains, accidents attributed to human error persist. If human factors efforts can affect the incidence of error, then the lack of their effectiveness may be the identification of the factors contributing to error. This paper addresses that possibility by presenting a human factors approach to the identification of factors that contribute to error and the development of error prevention strategies whether they involve training, design of new equipment, equipment modification, or policy change.

The following discussion describes an error data collection effort designed to provide sufficient information to identify the problem and target prevention strategies to specific factors that contribute to the problem. This involves two techniques: grounding the data collection effort in the perspectives of the user populations, and applying a systems model to the design of the data collection, analysis, and applications of the findings..

It should be noted that although this paper discusses the human factors approach in terms of developing a data collection effort, the approach also can be used to structure and analyze existing data collection activities. The effectiveness of the approach in existing activities is limited, however, because the perspectives of the user populations almost certainly were not considered in the development of the effort. The importance of those perspectives is addressed in the next section of this paper.

A number of steps are involved in developing an error data collection effort and identifying preventive strategies based on the findings from the data. For the purpose of this paper, the steps include: defining the problem, decomposing it into its constituent parts, determining the appropriate data to collect, devising a means for collecting data that will address the concerns of the users, and analyzing the data to provide meaningful findings. Those steps organize the following discussion of an empirically based, domain-free set of data elements which can be augmented to address the idiosyncratic issues of any specific domain.

#### **Problem Definition**

The definition of human error for the purpose of this paper is an amalgam of dictionary definitions of error: *Human error is an act, assertion, or decision that deviates from a norm and results in an actual or potential adverse incident. That incident may or may not eventuate in an adverse outcome. The norm which defines an error is consensually accepted by the constituents of the domain under consideration. An error may reflect a number of factors or may, be the final act in a series of contributing errors, i.e., a cascade of errors.*

There have been a number of refinements of the term human error. The rubric of error has been differentiated into slips and mistakes (Reason, 1990) as well as being linked to a level of performance as in AM-based, rule-based, or knowledge-based activity (Rasmussen 1986). To have a simple definition of error for ease of conceptualization and discussion in this paper, those refinements although admittedly useful for more detailed considerations, are not addressed.

Human error is not unique to any one domain. There is ample documentation of human error in industries such as aviation, nuclear power, and health care. The observation that error is ubiquitous and has been over time is confirmed, albeit only for a certain class of error, by the existence of a mechanism in the human brain that is dedicated to monitoring a person's performance and compensating for errors (Dehaene, Posner, and Tucker, 1994). The class of errors which activates this mechanism is that of errors detected in time for a correction to be attempted, i.e., near misses.

Errors that are near misses should be considered in an error data collection activity because what is a near miss for one individual may be a fatal error for others. Information on near misses can only be captured from the person experiencing the error. Similarly, information about what actually occurred in any error can best be provided by the person experiencing the error. The perspective of those who experience errors, i.e., those who use the data collection instruments by responding to them is rarely considered. Typically, the users of data collection activities are presumed to be the professionals who collect and analyze the data.

The data collection and analysis activities described in this paper, consider the perspective of two groups of users: those who report the information and those who use the information. If the information from the former group of users isn't viable, then the products from the latter group may not be accurate and lead to ill conceived preventive strategies. Because the perspective, of the information providers is central to the success of a data collection effort, the data collection activity should be designed and organized for relevance and acceptability by the respondents as well as providing the necessary information to the data collectors. The inclusion of the perspectives of both groups of users throughout the ensuing discussion is implicit when not explicit.

Errors are broadly categorized by their outcome: an adverse incident which nearly occurs, i.e., a near miss; an adverse incident which occurs, but its impact is immediately reversible; an adverse incident with an adverse outcome lasting 3 months or less; an adverse incident with a long term (more than 3 months) adverse outcome; and an adverse incident resulting in death. This paper addresses only errors which are quantifiable either directly or indirectly. Near misses are quantifiable via the report of the person involved. Although efforts to reduce the likelihood of an error and reluctance to report an error are related the severity of its outcome, outcome is only tangentially considered in this discussion of error identification. The focus of the paper is error, not outcome.

Human error is considered as having two components: behavior that is determined to be erroneous, and the conditions in which the error occurred. The broad categories of behaviors consist of acts, assertions, and decisions which may lead to near misses, adverse incidents, or

adverse outcomes. There also are two components to the conditions in which the error occurs: the contributing factors, both proximal and distal and the preceding or anticipated circumstances. This consideration of error inducing conditions is structured by decomposing them into categories of contributing factors.

### **Problem Decomposition -- Contributing Factors**

Given the vagaries of human beings, it is unlikely that error ever will be eradicated. The incidence of error, however, can be reduced by targeting preventive activities to the factors that contribute to it. Those factors can be identified by decomposing the problem through analyzing the conditions in which the error occurred and developing data elements to reflect those factors. Determination of categories of contributing factors can aid this process by focusing the analysis.

An error involves more than the person associated with the error even in the apparent solitary act of decision-making. It is necessary for an individual to have something about which to make a decision. Decision-making entails at a minimum, the psychological cognitive, and perceptual facilities of the decision maker and an entity or set of circumstances to stimulate those factors. Even the most intra-personal/intra-psychic error involves extra-personal factors. This diad can be conceptualized as a system of the individual and the extra-personal factor(s). Thus, error reflects an event of a system. If the basic unit of consideration meets the criteria for a system then it is reasonable that a systems approach be applied to the problem of error identification.

Moray (1994) has proposed a domain-free systems approach that consists of a hierarchy of levels of description. The hierarchy starts with equipment, followed by the physical ergonomics of the equipment, the behavior of the individual using the equipment, team and group behavior, organizational and management behavior, legal and regulatory rules, and finally societal and cultural pressures under which all else operates. These levels assist the analysis of the problem of error identification by providing structure for the decomposition of human error into broad categories of contributing factors.

The literature suggests that there is a core of factors that contribute to error regardless of the domain in which the error occurs. Those empirically based findings are included in the decomposition of problem of error. The well documented error-contributing factor of fatigue (Kreuger, 1994) provides an example. That factor is induced by the conditions such as consistently working extended hours or varying shifts. A preventive strategy directed to the individuals might be to instruct them to spend more of their off-work hours sleeping. This is not necessarily a realistic admonition. Using the systems approach, fatigue is considered in terms of its cause, the work schedule, which is within organizational and management behavior. Thus, preventive strategies to reduce the likelihood of fatigue induced error would be directed to the organizational and management component.

In addition to the classes of contributing factors within the hierarchical categories that are common across domains, there are idiosyncratic characteristics of each of the domains. These characteristics are domain-specific foci for the common contributing factors. For example, the

organizational and management behavior category, there is the class of delegation of responsibilities. Delegation of responsibilities for an airline cabin crew with respect to the cockpit crew has different foci from that for personnel in a hospital's intensive care unit with respect to the emergency room staff. To best represent the actual nuances of the contributing factors, the foci should be developed from the respondents' perspective as well as that of the data collectors,

### **Data Element Determination to Capture Acts and Circumstances**

To be relevant, data must reflect the problem being addressed, i.e., human error. This involves capturing information about the erroneous act or behavior and the circumstances, the context of the situation in which the act occurred from the perspective of the respondent. For the purpose of this discussion, the situation in which the error occurs can be envisioned as a vertical representation of the contributing factors within the categories of the systems approach. The circumstances are factors in preceding or anticipated situations which contribute to the error. Circumstances can be represented on a horizontal time line.

The circumstantial factors do not directly affect the person, yet they contribute to the error. The influence of circumstances is intra-psychic; however, the contributing circumstantial factors can be documented by records of previous activities or schedules of future ones. For example, a person omits a critical step in an operational procedure for no apparent reason, i.e., the work conditions are as usual with no observable stress or fatigue and the equipment being operated equipment is familiar. Analysis of circumstances finds that the person observed a fatal incident the previous week and is scheduled to use the equipment that was involved in that incident during the next day. This could be pre-occupying the person and contribute to the omission. Further information should be gathered and preventive strategies developed.

To provide as complete a picture as possible of what leads to human error, the elements of an error data reporting activity should tap into the respondents' experience with the erroneous acts and the contributing factors in the specific situation and circumstances in which the error occurred. The elements should be designed so the respondents provide sufficient detail about the error and the context in which it occurred to identify all contributing factors. Those factors then can be organized into the system categories for analysis and use in targeting preventive strategies.

Because every aspect of human endeavor evidences behavior that is judged erroneous, it can be assumed that some consistency in characteristics of erroneous behavior exists across domains. This consistency can be found in ongoing research and training activities in various domains as well as in the empirical literature. Similarly, because the conditions in which errors occur are finite and even similar across domains, it can be assumed that classes of factors that contribute to that behavior might be identified. In addition, there are intra-personal consistencies across errors and situations. For example, some people tend to blame themselves for an error when the contributing factors actually are external to them. These people are considered to be intrapunitive rather than extra-punitive (Sellen, Senders, and Russell in press). Data elements should be designed to address this tendency as well as other consistencies.

Given that the purpose of the data collection activity is to develop prevention strategies to reduce the likelihood of the error, it is imperative that the data elements elicit information which after appropriate analysis, indicates the conditions in which the error occurred and the contributing factors. It is not uncommon that data collected by a problem reporting system reflect the occurrence of a problem with only the readers' imagination to determine the contributing factors. An example of such a report is: "Person X experienced a severe injury when person Y raised widget Q on which X was standing. Widget Q was inspected and found to be functioning in accordance with its specifications." Such a report would be interpreted as indicating that human error was the cause because the equipment, widget Q, was functioning according to its specifications. What prevention strategies might be developed from this information?

Numerous comparable reports may be received from a reporting system which collects data as in the previous example. From such data, it can be stated that human error with Q caused severe injury in Z number of instances. Although providing information for summary statistics, these data provide no viable information to address the problem. That is, no information is provided to identify: what aspect of Q might contribute to the problem any deficiencies in the skills and abilities of Y, circumstances of the work environment that affect Y's behavior, or contributing factors in the process of using Q that contributed to the error.

The example underscores the importance of data elements that provide sufficient, appropriate information to accomplish the purpose of the data collection activity, i.e., develop prevention strategies. In addition, data elements should be designed in a way to elicit information from the respondents, i.e., the data elements should be acceptable to the users of the data collection instrument. The phrasing of the elements should be unambiguous, the elements should be simple and concise, but not preclude detail. The elements within the categories of contributing factors should stimulate the respondent to address all aspects of the situation. The elements should elicit extra-punitive contributing factors from intra-punitive respondents.

In striving to develop data elements from the perspective of the respondents, it is necessary to consistently consider the issues of quality and quantity of data elements from the perspective of the other group of users -- those who will code and analyze the data and ultimately use the findings to develop strategies to prevent error. The elements should be designed for ease of coding yet be amenable to the respondents. The elements should allow the response to be focused, yet allow for elaboration that can be readily coded.

Both groups of users should be involved in the final determination of the data elements. Previous data collection efforts in the domain under consideration and other domains to the extent possible, should be analyzed and lessons learned, both positive and negative, applied to the current activity. This provides an expanded empirical basis for the data elements.

## Data Collection

To optimize the effectiveness of the data collection for both groups of users, it is necessary to design and implement that activity in accord with its purpose of obtaining information about error. Collecting error data has particular problems; there is a major accessibility issue of the repercussions from reporting errors. Given the current propensity of our society to solve all problems through litigation, the possibility of personal liability from error reporting is a non-trivial factor in collecting error data. Common parlance is that the Aviation Safety Reporting System (ASRS) has successfully circumvented that concern to a considerable degree. Thus, the ASRS provides lessons learned that are valuable to all domains involved in collecting error data.

Another facet of effective data collection is that of accessibility of the data reporting instrument to the respondent. If the means for reporting data is not available or is inappropriate for the task, then it won't be used and even the most sensitive data elements are for naught. A paper form has high accessibility to the user whereas a computer terminal may be relatively inaccessible. Information from the paper form particularly a written narrative, may be very difficult to read, resolve ambiguity, and code. Direct entry into a computer is readable, however, coding of a narrative remains a problem.

For accuracy and completeness, data pertaining to an error should be collected as close to the time and location of the error occurrence as possible. These qualifications argue for collecting data via a palm-top computer or possibly a small lapel-mounted tape recorder from which the data would be transcribed and coded to conform to the data elements. The miniature computer and the transcription and coding of audio recorded error descriptions probably are not feasible due to fiscal constraints. An affordable alternative might be for the respondents to reply to the elements presented on a written form via audio tape which could be computer coded.

How representative the number of errors reported is to what actually occurs within a given domain is of tantamount concern. Under-reporting leads to inappropriate representation of the magnitude of the problem. Preventive efforts based on under-reported information although well conceived and directed, may not be effective because the portion of the problem addressed is insufficient. This could lead to an effective preventive effort being considered ineffective.

Skewed reporting, i.e., data collected which disproportionately represent one among many contributing factors could lead to preventive activities that appear to be ineffective for the problem while actually being effective for the aspect of the problem identified. These examples emphasize the importance of thoroughness in data collection and suggest that the process of data analysis be carefully executed so that its potential can be realized.

## Data Analysis

Issues to be addressed by the analysis of data should be determined prior to the development of the data elements. Data elements typically address a narrowly defined problem; however,

additional information for a nominal increase in effort might be provided by further analysis of responses to some data elements.

The analysis of data for the development of preventive strategies is driven by the identification of what constitutes error, factors both proximal and distal that contribute to the error, and sources of those factors. Another purpose of the interpretation of the findings from the data analysis could be an explicit as well as implicit evaluation of current preventive activities. That would provide lessons learned information which can be particularly useful for a domain's geographically distributed activities. The information could be applied to a planned activity that is comparable to one implemented elsewhere.

The analysis of data can produce findings which are applied to the purpose of the activity. It also can produce findings that contribute to the research literature. This dual use of data analysis, that of application and research, is iterative (Bogner, 1994). Findings from the data analysis can be used to direct the development of preventive strategies activities to a specific error, and contribute to the, refinement of the data collection activity and elaboration of the models upon which it is based. Those refinements when reported in the research literature can be integrated into the development of other data collection activities within the specific domain or across domains. The process is repeated with further refinement of data collection activities and enrichment of the literature that may have a number of applications both within and apart from error data collection activities. Such uses of data multiply the impact of resources.

## Summary

Rather than error being considered a shameful act to be buried for fear of being punished, error should be considered a flag, an occurrence indicating a problem to be solved. From the systems perspective, an error will persist regardless of the individuals involved until the circumstances that induced the error are remedied. The problem is in the system not the individual so shame and blame are not appropriate. Efforts directed to reducing the likelihood of the recurrence of an error should be directed not just to reducing the error *qua* error, but to redressing the conditions that caused it

There are several audiences for the reports of the findings from the data analysis which are represented by the categories of contributing factors in the hierarchical systems model e.g., organization and management personnel and those concerned with legal and regulatory issues. From those findings, each audience can affect preventive strategies which synergistically can impact the problem. In some instances, formal organized activity may not be necessary; performance can improve in a performing unit when that unit is given a report of its activity together, with comparison data for comparable units (Barbour, 1994).

Two approaches to error identification were presented in this paper both of which represent the application of a human factors approach to error identification. One approach is that the perspective of each of the groups of users should drive every aspect of the error data collection

activity. The second approach is that a systems model is an effective guide for the development and implementation of the data collection activities and preventive strategies. These approaches not only are parsimonious as advocated by Occam's razor, they are good business because they enhance the impact of scarce resources by building on previous work and affording multiple uses of the findings.

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