

HUMAN FACTORS AFFECTING THE PERFORMANCE OF INSPECTION PERSONNEL  
IN NUCLEAR POWER PLANTS

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INTRODUCTION

The maintenance and safe operation of nuclear power plants is a major concern of the utility industry. Of particular interest is the development of competence in flaw detection among inspectors who perform IGSCC (intergranular stress corrosion cracking) inspection. Despite efforts focused on the implementation of stricter qualification codes, the remediation of skill deficits (e.g., training efforts), and equipment upgrading, two problems remain:

- There is a relatively low pass rate on the qualification exams among workers who attend the EPRI NDE Center's IGSCC detection course; and
- Of those who are qualified, there is an apparent disparity between their good performance in training and poor field results.

The question of poor field performance begs several other fundamental questions; for example, "What is a competent or effective worker?"; "How can we distinguish a good worker from a poor one?"; "Are the criteria for evaluating poor performance similar at training and in the field context?"; and "Under what conditions will a given examiner perform most effectively?"

These issues and the normative questions they raise represent perhaps the most urgent area of concern. However, to date the complex question of why field performance is "less than optimal" has yet to be satisfactorily answered.

It is understood that detection of IGSCC flaws is regarded as a specialized function that imposes very demanding task requirements on the human operator. However, this investigation was intended to explore, in considerable detail, the wide range of psychological mechanisms and relevant human factors that may be associated with poor performance among IGSCC inspection personnel.

### Review of Past Studies

Past studies to date have tried to analyze and quantify effects of tasks, tools, skill, and cognitive information processing elements in man-machine systems. Yet, it seems evident that the proportion of emphasis in research on human factors is out of balance.

Although this vast literature has clearly demonstrated the fruits of spending millions of dollars to optimize equipment and technology, and the establishment of programs to train and qualify operators, there is also clear evidence of underinvestment in the most complex piece of "machinery" in complex systems: the human.

### CONCEPTUAL FRAMEWORK

A systems approach was employed to provide a comprehensive analysis of the problem and to integrate the literature. This conceptualization attempts to explain the organized pattern of behavior (performance) across individuals and across occasions of performance within individuals. Here, the worker is viewed as an open, living system capable of self-direction and change. In this light, performance is not random. Rather, performance is purposeful and is organized by three aspects:

- o The goals of the person (what outcomes the person wants to attain or avoid);
- o The person's behavioral and biological possibilities and limitations; and,
- o The content within which the person is functioning.

The context includes environmental constraining and facilitating conditionalities (i.e., what are the rules, expectations, opportunities, and limitations in a given situation?).

Accordingly, workers' final decision regarding a flaw may be shaped by a multiplicity of internal (personal) as well as external (environmental) factors. In particular, because of the central role that goals and context play in the organization of behavior, poor performance is not to be equated with personal deficiency. The same person who is deficient in one task may prove to be quite efficient in another.

Thus, the question is not whether performance is determined by the person or by the situation, or even how much is determined by the person and how much by the situation. Rather, the emphasis is on the patterned, organized quality of behavior in a person-environmental system characterized by constant change in both internal and external (situational) requirements. This implies that what constitutes a manageable or pleasant environment for one person may be an unmanageable or unpleasant one for another. Moreover, what competence means to a person in one situation may be quite different from its meaning in another situation.

Based on this conceptualization, two separate, yet related, approaches were adopted to identify human factors that may influence performance:

- o A theoretical or "top-down" approach, in which effective performance is construed as a product of a skillful, motivated person interacting with a responsive environment; and
- o An empirical or "bottom-up" approach, in which effective performance is defined by people's conception of a competent worker and/or a productive work episode.

#### THEORETICAL OR "TOP-DOWN" APPROACH

Application of this approach to the extant literature revealed that workers' poor performance can be best understood as being primarily a function of contextual and motivational factors. Although skill is a crucial component of effective performance, the evidence suggested that it can readily be acquired through technical training. A brief analysis of the most relevant contextual and motivational factors and the ways in which they may influence performance follows.

#### Contextual Factors

The nature of IGSCC inspection work suggests that workers' competence may be strongly influenced by the contexts (physical and social) within which they operate. Variations in contextual conditions and contingencies may positively or negatively influence the work outcome in different ways. For example, the physical environment of the power plants (e.g., machines, radiation, heat, etc.) may significantly degrade performance for some individuals. Similarly, the standards, attitudes, and practices of supervisors and ISI managers may influence the relative value of performance.

Thus, the outcome of inspection work (e.g., flaw detection, missed cracks, or false calls) can not be regarded as "good" or "bad" per se. Rather, performance can assume meaning only when it is evaluated within the context in which it occurs. In some cases, the very behavior that is rewarded in one context (e.g., training) may be responded to quite negatively in another context (e.g., the field).

For example, a skillful technician who has passed the NDE Center's qualification examinations may be considered competent according to the IGSCC qualification standards. Yet, the same person may appear to perform less efficiently in the field context because (a) he/she may not be able to endure the physical hardships of the plants; or because (b) he/she may now be functioning under a different set of values, standards, or directives from those learned in the training context. Workers manifesting this pattern of performance are likely to be regarded as "incompetent" despite their demonstrated effectiveness in at least one assessment context.

#### Motivational Factors

Within any given context, behavior is meaningful and motivated to the extent that it is guided by (a) a coherent purpose (directive functions); (b) high standards of professional conduct and the belief that effective performance is possible (regulatory function); and (c) the availability of attentional and emotional energy resources (arousal functions).

For example, many examiners may not be attracted to a job as difficult as IGSCC flaw detection and may intentionally do poorly on qualifying exams to avoid it. Alternatively, those who are more concerned about job security and a steady income may be willing or even eager to try to perform competently both in training and at the work site. Yet those who are "intrinsically" motivated to do good work (i.e., those for whom doing a good job or mastering the challenge of work is its own reward) may be the most consistently effective workers. Such workers are unlikely to be satisfied with minimal or ambiguous performance. In contrast, examiners whose activity is guided by "extrinsic" goals (e.g., money, fear of loss of job) are likely to behave in a somewhat more erratic and less committed manner.

Workers may also perform poorly in the field context because they may be unskilled in making decisions and solving problems in a complex informational environment. Or, they may lack the attentional and emotional resources needed to perform the difficult task of IGSCC detection. The physical and mental stress associated with this job may quickly deplete available energy resources in some individuals and lead to a lack of efficiency, productivity, or good judgment. Both anxiety and boredom can take their toll in this regard.

Finally, in situations where informational and supportive feedback is not readily available (as is often the case in the field context), workers may develop negative beliefs about their capabilities and opportunities for exercising them. Under such circumstances, performance can quickly deteriorate due to the inhibiting influence of these beliefs.

#### EMPIRICAL OR "BOTTOM-UP" APPROACH

This approach was used to conduct two separate studies that were designed to substantively and methodologically supplement one another. Both studies share the objective of identifying the relevant "person" and "environment" variables that influence performance. However, they differ in terms of their overall design and policy limitations.

Study 1 focuses on the global traits of the workers and is primarily relevant to the problem of personnel selection. Study 2 focuses on specific episodes of work performance and is therefore more relevant to the problems of training and management practices.

#### Study 1

A series of semistructured interviews of approximately one hour in length were conducted with 37 subjects representing a cross section of the industry (i.e., workers, ISI supervisors, ISI vendors, and training staff). These interviews were designed to elicit statements about characteristics of a highly competent worker. The results of this study revealed the following:

- o There is a diverse but relatively consistent attributes that people in the UT ISI industry use to describe a competent examiner. These attributes can be organized in seven major clusters (Figure 1). The attributes most commonly associated with effective performance across the four groups of respondents were conscientiousness, stress tolerance, knowledge, and self-efficacy. Three of these clusters represent motivational characteristics. In other words, the data suggest that an ideal worker should be highly and intrinsically motivated to do a good job despite an unresponsive environment (e.g., despite the stress-producing conditions that occur during outages at nuclear power plants).

- Although there was considerable agreement among subjects with regard to their nomination of attributes, the frequency of mention of each of the 26 characteristics was not consistent across the four groups of respondents. This finding reflects the normative nature of judgments about competence, and thereby the subjective viewpoint of each of the groups and their evaluations regarding goals, costs, and benefits, values, priorities, and standards.
- Because selection of criteria is a crucial step in assessing competence, the results of this study may serve as starting point in developing an index of effective performance.

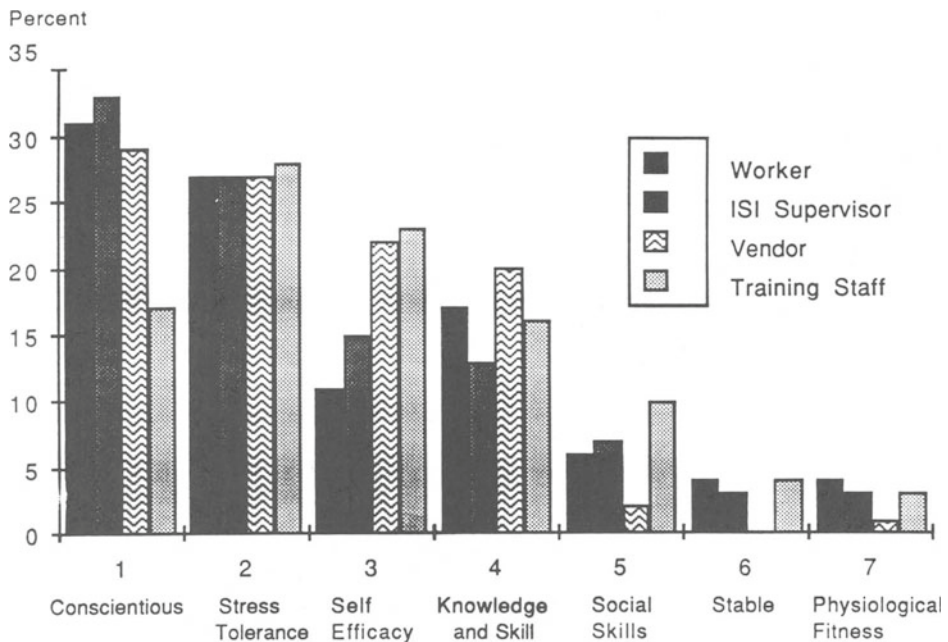


Fig. 1. The prototype of a highly competent worker. Figure shows that there are diverse yet relatively consistent attributes that people in the ISI industry choose to describe a highly competent examiner. However, there are variations in responses among the four groups of respondents.

## Study 2

This study was designed to elicit descriptions of "typical," "superior," and "unusually poor" situations or occasions of performance. A sample of 100 episodes was generated from 20 subjects (eight examiners, three training staff, eight ISI supervisors, and one vendor) during a series of semistructured interviews of approximately one hour in length. The results of this study revealed the following:

- Respondents' descriptions of typical, superior, and unusually poor episodes focused on eight major components, including four worker-related attributes and four context-related attributes (Figure 2).
- Specifically, among the contextual factors preplanning (e.g., scheduling and preparation), managerial and supervisory cooperation and support, and efficient organization appeared to be the most salient factors contributing to good or poor performance outcomes. Among the person factors, preplanning (e.g., preparation) and professionalism were the most salient factors.

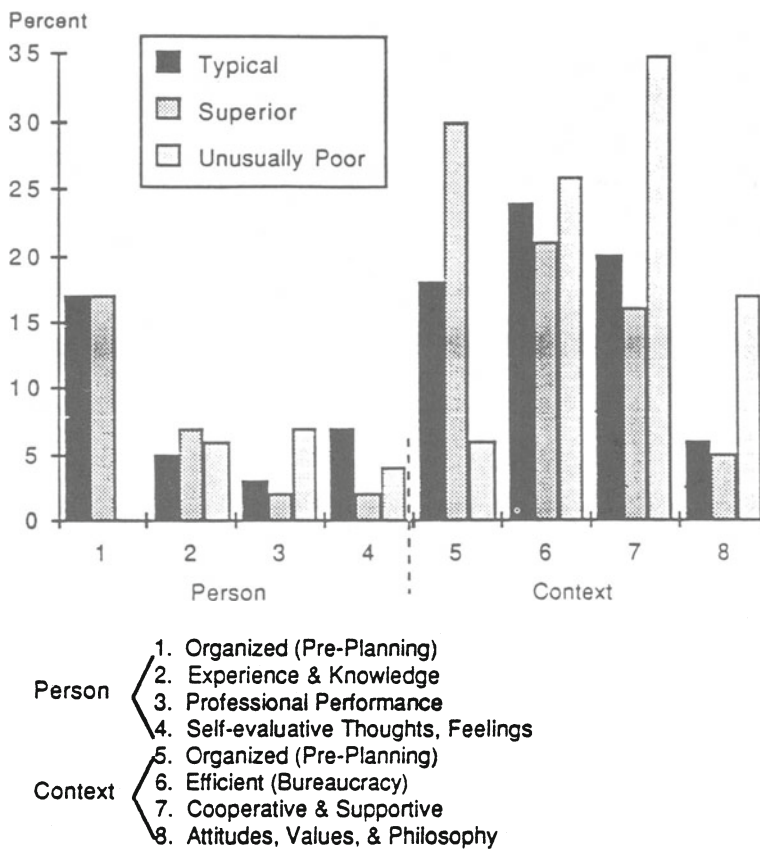


Fig. 2. Attributes of typical, superior, and unusually poor episodes. Figure suggests that both the person (worker) and the context characteristics as a unit make up the ingredients of an outcome in a specific situation. However, the contextual factors appear to play a more salient role in the sense of eliciting different performance outcomes.

## PRACTICAL IMPLICATIONS

The findings of this investigation suggest that contextual factors (e.g., supervisory and ISI managerial practices) are the major determinants of the outcome of performance--assuming that workers have the basic skills.

These results offer some guidelines for practice and future research in two areas: (a) management and training practices, and (b) the selection of personnel. These aspects (a and b) correspond to the two policy questions that guided this investigation.

### Management and Training Practices

One way to improve performance is through changes in ISI management and training practices. This option is most appropriate in situations in which the social aspects of the context are operative. This investigation has illustrated that the motivational state of the worker is largely a function of his/her current working conditions. To improve the motivational state of workers, the following three practical options may be adopted:

1. Some of the existing managerial practices in the field context may need to be altered.

For example, the ISI management attitudes and practices may be altered to cultivate workers' autonomy, their professional and independent judgment, and to reduce their work-related frustration. The kinds of positive feedback that appear to be most desirable are those that are geared toward (a) immediate task performance, so that the worker can work in a supportive and learning environment, and (b) helping workers to develop positive personal agency beliefs, in part by helping them learn and internalize both explicit and implicit rules and standards of conduct.

2. Training programs may need to be reformulated in an effort to accommodate the existing discrepancies and possible informational gaps between training conditions and the field.
3. A more standardized code of managerial conduct may need to be established by the utility industry.

### Selection of Personnel

Another way to enhance performance is through improved selection. This option is perhaps most desirable in situations where environmental conditions are difficult but not alterable (e.g., hostile working conditions of heat, noise, humidity, radiation, etc.), or in situations where social changes in training or management practices are not likely to be forthcoming. In this light, the industry may need to insure through active recruitment practices, careful application of selection criteria, or modification of its qualification codes that most consistently competent workers enter the work force.

The prototype of a highly competent examiner from Study 1 may serve as a starting point to develop an instrument for this kind of selection purposes.

## CONCLUSION

This study demonstrates a nontraditional approach to studying the problem of inadequate performance among nuclear power plant inspectors. In the past, there has been a heavy reliance on automation, and a tendency on quick action rather than reflection.

The type of human problems discussed in the preceding summary, although they are imbedded within a technical system, are in reality non-technical. In other words, humans are not machine-like entities. Their behavior is governed by goals and variable capabilities and limitations in adopting to the context within which they function.

Therefore, in studying human problems one must be prepared to accept the discomfort of dealing with the ambiguous nature of social psychological interactions and to incorporate them into the design of any study.

This is not an easy task, given that such fundamental changes may require a reorganization of goals and policies with regard to the role of IGSCC inspection personnel. Moreover, any change at the policy level requires an open orientation and a constructive outlook on the part of researchers, practitioners, and policy makers toward possible future consequences. It also requires a commitment to the process of change.

This investigation has demonstrated that the desire for change does exist among the various groups who are the active participants within the ISI industry. Yet, the extent to which various person and context factors are alterable and the ways in which they can be influenced may be the subject of further investigation and may ultimately rest on the industry's priorities, standards, and cost-benefit considerations.

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