Human Performance Tools

Engaging Workers as the Best Defense Against Errors & Error Precursors

By Jan K. Wachter and Patrick L. Yorio

IN BRIEF
- **To prevent human error from affecting operations, management can 1) keep workers from making active errors (error avoidance) or 2) stop the errors from having an effect (controls).**
- **Human performance tools have been designed to help workers anticipate, prevent and catch active errors. Many tools are geared toward identifying the presence of error precursors.**
- **Based on interviews conducted with high-performing organizations, the top 10 human performance tools have been determined. These tools are effective because they provide error-avoiding defenses and promote active worker engagement.**

Consider these three related truisms: *To err is human. Workers are fallible. Errors are inevitable* (as well as predictable). These are some fundamentals of the human performance approach to understanding safety. Generally speaking, human performance encompasses the way workers, the organization, the environment and the management system (e.g., programs and processes) work synergistically as an entire system. Workers are the focal points of this system, since any flaws in the system can affect workers' performance and, conversely, any worker flaws can affect the system. Errors are largely viewed as consequences of working in a flawed system.

Given this human performance perspective, it should not be surprising that workplace incidents are triggered by human actions and in many cases the human actions causing these events are errors (which are unintentional actions without malice or forethought). About 80% of all incidents are attributed initially to human error (Perrow, 1984; Reason, 1990; U.S. DOE, 2009a). The remainder involves elements such as equipment and material failures. But, when the 80% human error is analyzed in detail, the analysis reveals that most errors are associated with events that stem from latent organizational weaknesses, whereas about 30% are caused by individual workers interfacing "erroneously" with systems and equipment (U.S. DOE, 2009). Thus, incidents result from a combination of factors both within and beyond the control of workers.

Although error is universal, the traditional belief that human performance is a worker-controlled phenomenon and that failures are introduced to the system only through the inherent unreliability of workers is in itself an error of understanding. Since experience indicates that weaknesses in organizational processes and cultural values are involved in most incidents, reducing human errors that are often the result of organizational weaknesses will reduce the likelihood that such events will occur.

Susceptibility to error is heightened when workers operate within complex systems that contain concealed weaknesses. These latent conditions either provoke error or weaken controls against the consequences of error. From a human performance perspective, Figure 1 diagrams the framework for incidents involving these organizational and human elements. The two ways to prevent human error from affecting operations are to 1) keep workers from making errors (error prevention) or 2) stop the errors from having an effect (controls). Figure 1 provides clues regarding intervention mechanisms that workers can use to prevent human error arising from the provocation of error at the workplace or the weakening of controls. Breaking the component linkages as presented in this figure prevents events from occurring. Using this model, events can be avoided.

This article explores the human performance tools workers can use to defend themselves against

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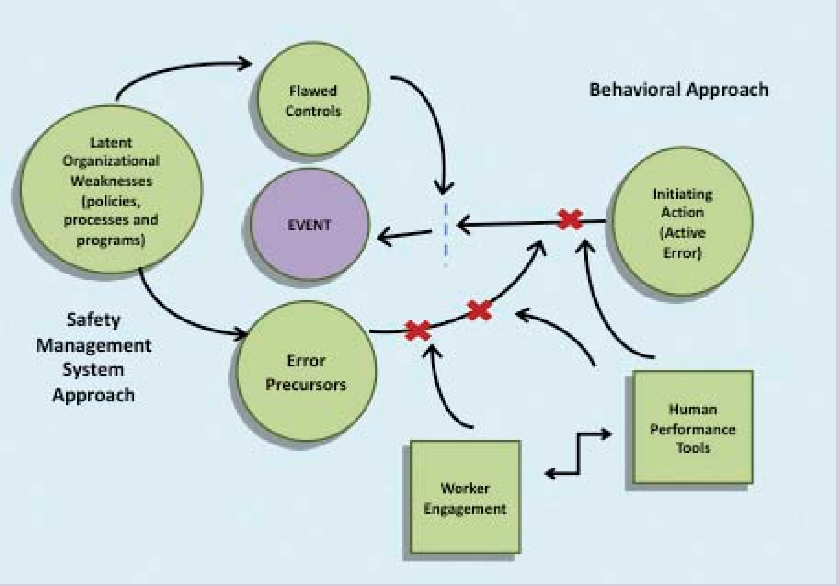
flawed organizational safety management systems as well as their own fallibility in order to reduce human error and, thus, workplace incidents. In a study sponsored by the Alcoa Foundation, the research team canvassed several known high-performing organizations in various sectors (e.g., nuclear operations, power generation, aviation, heavy manufacturing, government) regarding the human performance tools they have successfully used to reduce error and improve safety performance.

These tools are discussed in this article. They are emphatically worker-centric in that they engage workers to be more aware of their safety, error precursors, tasks to be performed, and their conditions and surroundings. Discussion will also address why engagement and other factors are critical in making these tools effective. However, to fully understand these tools and how they work, let's first review the human performance approach to managing and reducing error.

Figure 1

Framework for an Event From a Human Performance Perspective



A Primer on the Human Performance Approach to Reducing Error

The information presented on the human performance approach to reducing error has been largely adapted from the works of the U.S. DOE (2009a, 2009b), Reason (1990, 1997), Dekker (2006), Petersen (1998) and Performance Improvement International (2000).

What Are Latent Organizational Weaknesses?

Latent organizational weaknesses are hidden deficiencies in management processes or values which can create workplace conditions that provoke errors and their precursors and/or degrade the integrity of controls (Figure 1). These weaknesses lie dormant until uncovered—typically during incident investigations. These weaknesses either create the preconditions for error, or fail to prevent, catch or mitigate the effects of error. Latent errors are normally management's to identify and resolve. However, workers often are in a position to observe the preconditions for error, such as workplace distractions, that result from these latent organizational weaknesses. Many human prevention tools help workers discern and deal with these error preconditions.

What Are Initiating Actions & Active Errors?

Typically, workplace incidents are triggered by human actions, which can be acts of commission or omission. These errors are human actions that unintentionally depart from expected behaviors or performance. Active errors are physical, initiating actions that have immediate, observable and undesirable outcomes. Workers on the front-line commit most active errors because they "touch" the work, task or equipment. Most errors are insignificant in nature, resulting in few or no consequences. However, since most initiating actions are active errors, a strategic approach to preventing incidents includes workers anticipating and preventing active errors through the use of human performance tools.

Errors also can be categorized as slips, lapses and mistakes. Slips occur when physical actions (e.g., turn the wrong valve) fail to achieve their intended outcome. Lapses involve a failure of memory or recall (e.g., forget to turn off the valve). Mistakes occur when workers use inadequate plans to achieve the intended outcome (e.g., use an incorrect procedure to determine which valve to turn). Mistakes usually involve misinterpretations or lack of knowledge. On the other hand, violations involve the deliberate deviation or departure from sanctioned and expected behaviors, policies, rules or procedures. However, violations often are well-intentioned, arising from desires to complete the job according to management's direction.

Provoking Error: Is It Intrinsic in Human Nature?

Human error is provoked by a mismatch between human limitations and workplace conditions, including inappropriate management and

Humans & Systems Are Flawed

- Safety management systems and human nature are both flawed.
- Many incidents are initiated by human error.
- Human error is often a response to the presence of error precursors caused by management system deficiencies. Human error also is based on an individual's biases, vulnerabilities, assumptions and limitations.
- Worker-centric human performance tools that engage workers provide a defense against safety management system and human nature deficiencies.
- Many human performance tools increase employees' situational awareness and sense of mindful uneasiness to protect them from flaws in the organization and in themselves.

Table 1

Typical Error Precursors Found in the Workplace

Task demands	Individual capabilities and skills (worker specific)	Individual cognitive characteristics (worker specific)	Environment
Time pressure; high workload pressure; mental pressure	Unfamiliarity with task/first time or nonroutine or infrequent task	Assumptions, dispositions and habits	Distractions and interruptions
Simultaneous, multiple actions; multitasking	New techniques not used before	Overconfidence	Changes and departures from routine
Requirements for interpreting information and procedures; vague procedures	Lack of knowledge, proficiency or experience	Mental short cuts or biases	Confusing controls and displays
Unclear goals, roles or responsibilities; lack of clear standards; vague or imprecise work guidance; conflicting information	Poor communication or problem-solving skills	Limited short-term memory	Unexpected equipment conditions or performance
Repetitive or monotonous actions	Illness or fatigue; general poor health or injury	Inaccurate risk perception	Environmental factors such as noise, temperature and lighting
End of shift work; last shift before holiday; first shift back from holiday	Ability to handle stress	Unsafe attitudes	

Note. *Adapted from U.S. Department of Energy, 2009,* Human Performance Improvement Handbook, Vols. 1 and 2.

leadership practices and organizational weaknesses that set up the conditions for performance (or lack of performance). In some cases, however, errors are provoked by human nature. Workers may judge risk poorly, typically underestimating it. In addition, workers may overestimate the ease of success and their ability to perform.

For example, people may overvalue their ability to maintain control when they are working perhaps due to the lack of consequences resulting from most of their errors. Some workers operate under illusions of certainty that make them believe elements with risk are not risky. Also, there may be a general lack of appreciation of human limits, such as limited working memory and attention resources. The amount of information that can be held in working memory is typically limited to 7 +/- 2 items (Wickens, 1992). Working memory can create a logjam for incoming information. Various human performance tools are geared toward more accurately estimating risk levels of activities and dealing with human limitations.

Human stress can provoke error as well. Stress increases as familiarity with situations and conditions decreases. Workers generally try to avoid mental stress. Humans are reluctant to engage in lengthy concentrated thinking, as it requires high levels of attention for extended periods. Consequently, workers tend to look for familiar patterns and apply well-tried solutions to solve problems. This leads to the temptation to settle for less-than-optimal solutions rather than continue to seek the best solutions.

Mental shortcuts, or biases, are often used to reduce mental effort and speed decision making. Originating in the area of psychology, these include the following biases:

- **Confirmation bias:** Reluctance to change one's mind in light of conflicting information due to the investment of effort/time in the current solution.
- **Similarity bias:** Tendency to recall solutions from situations that appear similar to those that have proved useful from past experience.
- **Frequency bias:** The notion that a frequently used solution will work or giving greater weight to information that occurs more recently or frequently.
- **Availability bias:** Tendency to settle on actions that readily come to mind and appear satisfactory, or giving more weight to available information even if the information may be wrong.

Unsafe attitudes and at-risk behaviors can provoke error. Awareness of these detrimental attitudes or mind-sets (e.g., feelings of invulnerability; pride; heroic behavior; everything-is-fine attitude) among workers is the first step toward effectively applying error-avoidance methods.

However, many workers may find it difficult to see or admit their own faults, vulnerabilities or errors. Thus, many human performance tools are geared toward self-awareness of one's biases, vulnerabilities, deficiencies, assumptions and limitations, as well as on providing a more informed view of risk.

What Are Error Precursors & Error Traps?

Simply stated, error precursors are conditions that provoke error. They are unfavorable conditions that interfere with successful performance and increase the probability for error when conducting specific actions. These precursors are not cryptic or unintelligible to workers. They are observable and can be corrected. If these precursors are discovered and removed, work conditions can be changed to minimize the chance of error.

Error precursors can be grouped into four major areas: task demands, individual skills connected to accomplishing a task, individual cognitive capabilities and workplace environment. Table 1 lists typical error precursors found at workplaces in these four areas. Many human performance tools help workers take note of the presence of these error precursors.

Associated with the presence of error precursors are error-likely situations (e.g., situations in which the presence of error precursors are more common). Error-likely situations are those which present greater chances for error when performing certain actions or tasks in the presence of these error precursors (e.g., working on a particular piece of equipment that requires multitasking). Error-likely situations typically exist when the demands of tasks exceed worker capabilities or when work conditions aggravate the limitations of human nature. Error-likely situations also are known as error traps.

In a study conducted at Indiana University of Pennsylvania (IUP), the research team asked approximately 2,300 employees (some of whom worked at high-performing organizations) to respond to a series of questions regarding the presence of error precursors and working conditions in their organizations. Workers also were asked to report the number of injuries and near misses they experienced in the preceding 6-month period. Based on previous investigations, 6 months is the maximum time over which employees should be asked to recall injuries they have sustained with any accuracy (Veazie, Landen, Bender, et al., 1994; Zacharatos, Barling & Iverson, 2005).

Ten Likert-scale statements related to error precursors or worker conditions were provided and respondents were asked to indicate their level of agreement (1 = strongly disagree to 5 = strongly agree). The results are presented in Table 2. As shown, the most common error precursors identified were multitasking, high workload, time pressures and conducting nonroutine tasks.

Each response was then associated with the self-reported near misses, first-aid injuries and injuries resulting in medical treatment beyond first aid that were reported by each employee. These associations are reported in Table 3 (p. 57). As shown, most of these error precursor situations are systematically, positively and significantly associated with the number of near misses, first-aid injuries and injuries beyond first aid. Thus, error precursors are indeed associated with events in the workplace.

Table 2

Survey Results About the Presence of Error Precursors in the Workplace

Measure	Mean response	SD
At work, there are time pressures. I feel rushed.	3.44	1.05
At work, there are mental pressures. I find it difficult to concentrate.	2.94	1.03
At work, I conduct many nonroutine tasks.	3.31	0.99
At work, I conduct many new/unfamiliar tasks	3.01	0.97
At work, I typically have a high workload.	3.51	0.93
At work, I typically multitask—doing many different things at the same time.	3.72	0.95
At work, I receive work guidance that is at times vague or imprecise	3.06	1.02
At work, there are many distractions around me.	3.19	1.01
At work, there is low likelihood of management detecting a violation of safety rules.	2.71	0.97
At work, safety requirements are very inconvenient to comply with.	2.35	0.90

Note. *1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree*

What Are Modes of Performance?

Three modes of worker performance are key to understanding how and at what frequency errors occur, as well as how human performance tools can be used to combat errors when operating in these particular modes of performance.

Skill-Based Performance

Skill-based performance involves highly practiced, largely physical actions conducted in very familiar situations. Such actions are usually executed from memory without significant conscious thought or attention. In skill-based mode, workers function effectively by using preprogrammed sequences of behavior that do not require much conscious control. Examples are using hand tools, recording gauge information, using test equipment or clicking valve positions. One problem with skill-based performance is that the greater the familiarity with the task, the less likely the perceived risk will match actual risk. Workers become comfortable with risk and can eventually grow insensitive to hazards.

Inattention is the primary error mode for skill-based performance. Skill-based errors are primarily execution errors, involving action slips and lapses in attention or concentration. Under ideal conditions, the chance for error is less than 1 in 10,000, according to a study in the nuclear power industry. Roughly 90% of a person's daily activities are spent in skill-based performance mode. However, the nuclear power industry has found that only 25% of all errors are attributable to skill-based errors (U.S. DOE, 2009a).

Rule-Based Performance

Rules may be necessary for less-familiar, less-practiced work activities for which employees may not be highly skilled. Also, workers often switch to a rule-based performance level when they notice a

Table 3

Correlations Between the Presence of Reported Error Precursors & Near Misses, First-Aid Injuries & Injuries Beyond First Aid

Measure	Near misses	First aid	Beyond first aid
At work, there are time pressures. I feel rushed.	.19*	.10*	.08*
At work, there are mental pressures. I find it difficult to concentrate.	.16*	.08*	.06*
At work, I conduct many nonroutine tasks.	.12*	.06*	.04
At work, I conduct many new/unfamiliar tasks	.10*	.06*	.05*
At work, I typically have a high workload.	.11*	.02	.04
At work, I typically multitask—doing many different things at the same time.	.03	.03	.01
At work, I receive work guidance that is at times vague or imprecise	.16*	.08*	.05*
At work, there are many distractions around me.	.23*	.09*	.08*
At work, there is low likelihood of management detecting a violation of safety rules.	.16*	.09*	.06*
At work, safety requirements are very inconvenient to comply with.	.19*	.10*	.09*

Note. **p < .05; Polychoric correlations were calculated using scale data. This statistical method provides a better estimate of correlation between non-continuous variables.*

need to modify their largely preprogrammed behavior to account for some changes in work situation. In addition, certain job situations (including those that are safety critical tasks) simply lend themselves more to following a set of rules and procedures.

In rule-based performance, workers apply memorized or written rules to managing work situations. Typically, rule-based performance follows an *if* (symptom), *then* (do this) logic. In applying these rules, workers operate by matching the signs and symptoms of the work situation to some stored knowledge. One concern with rule-based performance is how to improve workers' interpretation of situations so that appropriate responses are selected and used. This is why written procedures (e.g., predetermined solutions to possible work situations that require specific responses) are prepared for anticipated situations.

Since rule-based activities require interpretation using an if-then logic, the prevalent error mode is misinterpretation. Errors include deviating from an approved procedure, applying the wrong response (e.g., procedure) or applying a flawed response (e.g., bad procedure). Rule-based errors are often classified as failure of expertise mistakes.

Rule-based modes involve making choices. The chance for error increases to roughly 1 to 1,000 (99.9% reliability). In the nuclear power industry, studies have shown that roughly 60% of all errors are rule-based (U.S. DOE, 2009a).

Knowledge-Based Performance

Workers enter knowledge-based performance when they are unsure what to do. Knowledge-based behaviors are responses to unfamiliar situations (where no skills or rules are recognizable to workers). Workers must rely on their understanding and knowledge, perceptions of present circumstances, similarities to previous circumstances, and the scientific principles and fundamental theories related to the perceived situation. Operating in this mode, to effectively gain more information about what they are doing or about to do, workers must be more focused than with skill-based performance. Knowledge-based situations are often puzzling and unusual to workers and the understanding of the problem is patchy, inaccurate or both. Knowledge-based errors are primarily lack of expertise mistakes.

Knowledge-based activities require diagnosis and problem-solving skills. Decision making can become erroneous if problem solving is based on inaccurate information. The prevalent error mode is an inaccurate mental model of the system, process or facility status. Thus, it is not surprising that workers do not perform well under these higher stress, unfamiliar situations in which they must think on their feet in the absence of rules, routines and procedures to handle the situation.

Therefore, under such circumstances, the chance of error is particularly high, approximately 1 in 2 to 1 in 10. In the nuclear power industry, studies indicate that roughly 15% of all errors are knowledge-based (U.S. DOE, 2009a). For many organizations that are embracing human performance philosophy, the goal is to move processes from knowledge-based to rule-based due to the fact that the error rates decrease by at least a factor of 10 in the rule-based mode.

In the IUP study, the researchers asked approximately 2,450 workers to respond to a question designed to determine which performance mode they

Table 4

Survey Results on Response Performance Modes Used in Error-Prone Situations

Question: When I am confronted with really abnormal conditions or unusual situations, my strongest tendency is to do which of the following:	Percent response
Skill-based response: I stop work and seek guidance as to how to proceed.	41.6%
Rule-based response: I apply rules, procedures, and protocols and use them as guidance as to how to proceed.	28.2%
Knowledge-based response: I draw upon my own existing knowledge and use it as guidance as to how to proceed (e.g., thinking things through on the spot).	22.5%

Note. *Number of workers responding to this inquiry was 2,449: skill-based* N = 1019; *rule-based* N = 691; *knowledge-based* N = 552, *and no response* N = 187 (7.6%).

would use to respond to uncertainty (e.g., error-prone situations, such as those associated with knowledge-based modes of performance). The results (Table 4) show that the most prominent performance response mode for survey participants is that found typically in skill-based operations (e.g., stop and seek guidance). It is encouraging that nearly half of the respondents are inclined to deal with uncertainty (when hypothetically pushed to operate in a higher-risk, knowledge-based mode) by using a skill-based response, which has the lowest rate of error associated with it. Safety-critical industries attempt to move from knowledge- and rule-based modes to skill-based modes in which error rates are lower.

Keys to Reducing Error

A strategic approach for improving human performance involves the anticipation, prevention, identification and recovery from active errors on the job, especially at critical steps, where error-free performance is absolutely necessary. Events can be avoided by understanding the reasons mistakes occur and applying lessons learned from past events and errors. Anticipating and preventing active errors often relies first on identifying error precursors and error traps, which is the primary role of many human performance tools.

One can take three basic approaches to reducing error: through planning, through performance, and through communication and feedback.

Planning

Planning activities can identify and control error precursors, traps and the potential for active errors. Planning includes identifying the scope of work, associated hazards and critical steps, and determining what is to be avoided; conducting jobsite reviews and walk downs (identifying potential challenges to error-free performance); performing appropriate task assignments (matching the right people to the job based on its task demands); and conducting task previews and prejob briefings (anticipating hazards, error precursors and possible active errors and their consequences). Such activities are the basis of many human performance tools.

Performance

During the execution of work, active errors can be minimized by performing work with a sense of uneasiness; maintaining situational awareness; avoiding unsafe or at-risk work practices; and being supported through the use of teamwork. Some effective human performance tools are geared toward achieving and maintaining this sense of worker situational awareness and uneasiness.

Communication & Feedback

Active errors may be averted by workers reporting workplace information (e.g., conveying information on the quality of work preparation, resource allocations and workplace conditions) to managers and by managers and workers conducting in-the-field observations (e.g., workers receive coaching and reinforcement on their performance through observation by managers and peers). Some human performance tools engage workers by promoting communication and feedback.

Worker Engagement

Are there general defenses that workers have within their control that will keep them safe and make them aware of their ever-changing surroundings, error-prone conditions, the fallibility of safety management systems and the limitations they have? The overarching answer perhaps is in the ability of workers to become engaged in the safety aspects of their work. Recent research (Wachter & Yorio, 2012a, 2012b; Yorio & Wachter, 2012) shows that safety management system practices and employee perception constructs "work" to improve objective safety performance by engaging workers (e.g., worker engagement acts as an important mediator between safety predictors and safety outcomes).

In engagement, an organization's workers execute their roles by driving personal energy into physical, cognitive and emotional labors and, by so doing, achieve active, full work performance. Engagement occurs when individuals are emotionally connected to others and cognitively vigilant (Harter, Schmidt & Hayes, 2002; Kahn, 1990). Connection and vigilance can be described as being psychologically present, attentive, integrated and focused in

Human Performance Tools

Human performance tools can be used to reduce human error. The specific tools chosen are frequently based on the employees' primary performance mode (skilled-, rule- or knowledge-based).

Using human performance tools reduces human error in various ways, including these possible outcomes:

- heightened sense of situational awareness concerning safety, presence of error precursors and error traps, tasks to be performed, conditions and surroundings;
- increased deliberation, cautiousness and mindfulness in workers as they approach and perform their tasks;
- more accurate estimates of risk levels of activities;
- higher levels of self-awareness, including a more informed understanding of one's biases, vulnerabilities, deficiencies and limitations;
- communication and feedback promotion, including facilitation of interactions with others;
- slowing down activities to give workers more time to think about tasks;
- identification of warning signals that indicate that the situation is degrading or trouble is brewing;
- recognition of assumptions that need to be challenged;
- continual improvement of procedures;
- higher levels of worker engagement.

their role performance. Therefore, given the strong mental and emotional being-there aspect of worker engagement, it may be viewed as an important defense against the presence of error traps and latent organizational errors.

Worker engagement in safety functions may reduce the probability of human errors by making employees more involved in and aware of their tasks/surroundings and associated risks (e.g., heightened sense of situational awareness), including the error traps that could be present. Thus, increased levels of worker engagement in safety activities could be related to increased safety performance as measured by standard safety outcomes (e.g., recordable case rates). Therefore, it is not surprising that the human performance error prevention tools being used by high-performing companies often are associated with high levels of worker engagement to make them effective.

Human Performance Tools

By improving human performance, active errors are reduced. By reducing active errors, organizations help eliminate unwanted events. Human performance tools are designed to help people anticipate, prevent and catch active errors. In short, human performance tools help workers maintain positive control of work situations. Positive control means that what is intended to happen actually happens—and it is all that happens.

These tools are oriented toward preventing active errors, and many of them work by detecting and recognizing error precursors, error traps and hazards. These tools are vehicles for providing mental and social skills that complement workers' technical skills to promote safe and efficient task performance, such as carving out time to think about work, particularly critical steps (Muschara, 2012) or the error traps associated with the work to be conducted. Many human performance tools deliberately slow work down; this is counterintuitive since error precursors often arise due to the deliberate speeding up of work planning and execution processes. When used conscientiously, these tools give workers more time to think about the tasks at hand—about what is happening, what will happen and what to do if things do not go as expected.

Many of these tools might be characterized as situational awareness tools. *Situational awareness* is defined as the accuracy of a worker's current knowledge and understanding of actual conditions compared to expected conditions at a given time and location. These tools help workers form an accurate understanding of the work and equipment environment, and foster an attitude sensitive to the presence of hazards, error precursors and error traps and the possible consequences of an error.

Situational awareness means that workers clearly understand the job requirements, equipment condition and work environment before acting. In short, the situational awareness tools improve workers' insightfulness and abilities to detect and respond to unsafe conditions they may not see otherwise. They are particularly helpful in skill-based work performance.

Other human prevention tools help workers look for warning signals (even slight warning signs) which indicate that the situation is degrading or that trouble is brewing. Some are geared toward looking for deviations or deviation drift from normal conditions. Others force workers to challenge assumptions. Assumptions tend to occur more often when workers experience uncertainty. Assumptions also can be a result of unsafe attitudes and inaccurate mental models. Since assumptions are often treated as facts, challenging them is important in improving mental models, solving problems and optimizing team performance (Summers, 2012).

Error detection or prevention depends on people. Some human performance tools force interaction with others or with workers themselves. For example, self-checking tools provide employees with the means to avoid or detect mistakes by having workers observe themselves, while peer checking and three-way communication tools engage other workers in this process.

The mode of performance often determines which human performance tool to use. Several tools are designed to help anticipate, prevent or catch skill-based errors. These include self-checking and three-way communication primarily, as well as previewing tasks, jobsite reviews, questioning attitude, stopping when unsure, peer checking and concurrent verification. Also, when working in skill-based modes, workers may benefit from triggers such as operating aids and reminders.

Rule-based errors can be detected and mitigated by using tools that promote self-checking and exhibiting a questioning attitude, and that encourage calling time outs, stopping work when workers are unsure, conducting task previews and prejob briefings, and performing peer-checks and concurrent verification. Peer checks are particularly important in helping workers avoid critical consequential errors. However, the primary tool suggested for rule-based work is procedure use and adherence. In addition, some errors that occur when working in this mode may be corrected through retraining in certain instances (e.g., when workers have misinterpreted procedures, requirements or rules).

Knowledge-based human performance tools include conducting prejob task briefings; project planning activities; problem-solving and decision-making methods; and peer reviews. For workers operating in the knowledge-based mode, where their understanding of problems are often incomplete and/or inaccurate, and where slow and thoughtful thinking is needed, collaboration with small teams of attentive, committed and experienced workers often facilitates problem solving and decision making.

However, the most fundamental tool for knowledge-based work is to stop when unsure. The organization must constantly reinforce that when workers are unsure of what to do, observe conditions not addressed in prejob briefs or work instructions, or feel uneasy, the proper action is to stop, reassess the situation, confer with teammates, supervisors or job experts, and proceed only when people agree that the task can be performed safely and correctly.

Corrective action to reduce knowledge-based errors is challenging. Coaching is a proactive solution that can help employees avoid error and its consequences when working in any performance mode, but particularly for knowledge-based modes.

The Top 10 Human Performance Tools

In a study sponsored by the Alcoa Foundation, the authors canvassed several known high-performing organizations in various sectors (e.g., nuclear operations, aviation, power generation, heavy manufacturing) regarding human performance tools they have used with success. The information was subjectively analyzed, and the 10 leading tools were identified and are presented here. Inclusion on this list was related to both the frequency of organizations using these tools and the perceived and actual impact these tools had on avoiding and reducing active errors.

Most of these tools are worker-centric in that they tend to engage workers to be more aware of their surroundings, error traps, tasks to be performed, conditions/surroundings and safety in general. Supporting information on these tools was adapted from Cornell, Kramme and Synder (2012); Ferguson, Ferguson and Barger (2012); Fisher (2012); Muschara (2012); Shockey, Holland and Shelby (2012); Summers (2012); and U.S. DOE (2009b, 2012).

Tool 1: Pretask & Posttask Briefings

The canvassed organizations identify pre/posttask briefings as a tool that works especially if it engages workers to take ownership and if the briefings are conducted from a human performance perspective (e.g., identifying error precursors, modes of performances and additional tools to be used during the day/task to reduce the potential for active errors). These briefings should be applied to nonroutine and routine work. Considering the number and variety of factors involved with a specific job, many things can change, even with simple, repetitive tasks; consequently, no work should really be considered routine.

Pretask Briefings

The intent is for workers to look through a human performance lens and have engaging conversations before beginning work. Topics can include critical tasks steps and their associated hazards, stop work criteria, safety precautions, potential error traps, applicable performance modes of operation (skill-based, rule-based, knowledge-based) and determining the high-risk activity for the day. During these briefings, roles and responsibilities, conditions, resource needs, PPE requirements and emergency procedures also can be discussed. Important questions include: What could surprise us? What may go wrong? What hazards have we considered? What hazards could be discovered? What is the worst credible thing that could happen? What conditions could stop this job? What do we want to achieve in this task? What do we want to avoid in this task? What can we uncover and prevent? What lessons did we learn from yesterday?

Pretask briefings often follow the S-A-F-E-R pattern:

•Summarize the critical steps.

•Anticipate errors and error precursors for each critical step.

•Foresee probable and worst-case consequences should errors occur at critical steps.

•Evaluate controls and contingencies at each step to prevent, catch and recover from errors and/or reduce their consequences.

•Review previous experience and lessons learned relevant to the specific tasks and their critical steps.

Posttask Briefings

During these briefings, staff should review job environments, identify program gaps and discuss corrective actions. These reviews are essential when complications have occurred, after completing a nonroutine or important work activity, or after each high-risk phase of an important project. However, this tool also should be used for routine work, especially where improvements have been identified.

Other topics covered may include unexpected outcomes, usability and quality of work documents, knowledge and skill shortcomings, deviations from standards, and adequacy of tools and resources. These briefings are important learning opportunities that can be used to identify latent organizational weaknesses, the presence of error traps and ways to reduce human error. In addition, workers must continually adapt to ever-changing tasks and job conditions. How adaptation occurred at the jobsite and necessary improvements can be discussed during the briefing.

Pre- and posttask briefings and pre- and posttask reviews are similar. However, briefings connote more communication and engagement with

By improving human performance, active errors are reduced. By reducing active errors, organizations help eliminate unwanted events.

workers, while reviews are often conducted independently of task employees (e.g., by supervisors and safety managers).

Based on the research conducted, it appears the best pre/postjob briefings involve workers taking control and ownership of these briefings. Some organizations provide marker boards on which workers can check off error traps that may be present for that day's tasks and identify performance modes that will be used and critical tasks.

Tool 2: Self-Checking/S-T-A-R

Most companies surveyed identified self-checking tools as important. These tools involve developing and implementing worker-based approaches such as S-T-A-R (Stop-Think-Act-Review). They are most applicable when operating in skill-based and rule-based performance modes, and are particularly effective for repetitive tasks. Self-checking helps workers focus attention on the appropriate action, think about that action, understand the expected outcomes and verify results. This tool promotes situational and self awareness.

Following is a description of the S-T-A-R steps:

•Stop (or slow down). Pause to focus attention on the immediate task.

•Think. Think methodically and identify correct actions to perform and understand what will happen when correct/incorrect action is performed.

•Act. Perform the action.

•Review. Confirm anticipated result has occurred or apply contingency if required.

This tool necessarily engages workers because they perform it on themselves.

Tool 3: Take-a-Minute/Jobsite Review

Jobsite review, popular for use in field locations, can improve workers' situational awareness, especially when first arriving at a jobsite. By taking a minute (sometimes referred to as a *2-minute review* or *take two*), workers explore the site and compare current conditions with prejob briefing information. Using this tool, deviations, unexpected hazards, precautions and complicating factors and conditions can be discussed, especially if these involve safety critical steps. Based on this revised risk status at the site, hazards can be eliminated, appropriate defenses can be installed or contingencies can be developed. This tool necessarily engages workers because they perform it themselves or in a team setting.

Tool 4: Stop & Seek/Stop When Unsure/ Pause When Unsure

Developing and implementing stop work criteria and seek help approaches/procedures are important, especially when workers operate in knowledge-based modes. This tool promotes awareness of workers' knowledge limitations as applied to dealing with specific work situations/deviations/ uncertainties. Workers will seek help (typically from supervisors and possibly coworkers) to continue work and deal with these uncertainties and/ or lack of knowledge.

The pause-when-unsure tool supports the notion that employees should approach their work deliberately, cautiously and mindful of their capacity to commit errors and of the presence of error precursors, error traps and hidden threats. This heightens workers sensitivity to the possibility of committing active errors. Again, this tool engages workers because they perform it themselves (e.g., self-manage it).

Tool 5: Questioning Attitude

Many high-performing organizations support a culture where questioning is an acceptable and promoted practice and value. A questioning attitude endorses a preference for facts over opinions and assumptions. It fosters thought about safety before actions are taken. It helps workers maintain an accurate understanding of work conditions at any given time. This tool is predicated on a stop-look-listen mentality.

One process that reflects a questioning attitude is described as follows: workers proactively search for situations that foretell uncertainty; they ask questions; they gather relevant information; they stop when unsure; they do not proceed in the face of uncertainty and ask for expert help; they proceed if sure and continue the activity if the uncertainty has been removed with facts.

This tool is worker-centric in that workers are in the best position to question actions and workplace conditions. Workers can question the presence of error precursors and error traps, as well as observed deviations. One way to use this tool is adopt it as a leading safety indicator for the organization.

Tool 6: Identifying Critical Steps

Critical steps are actions that will trigger immediate, intolerable and irreversible harm (if that action or preceding action is performed improperly). In terms of reducing human error, if critical steps are identified, then workers will be more cautious when performing these steps and should be less apt to operate erroneously using skill-, rule- and knowledge-based behaviors. This promotes workers' situational awareness and heightens the sense of uneasiness. Examples of critical steps are workers entering a confined space or touching a rotating pump. Once critical steps are identified, workers can anticipate errors that can occur at each critical step, estimate their consequences, then evaluate the existence of controls, contingencies and stop work criteria.

Tool 7: Coaching & Observation

Coaching and observation involve managers and workers. Some high-performing organizations have on-the-floor human performance coaches. Integration of human performance principles can be promoted by coaching workers on potential hazards, performance modes, error traps and the use of other human performance tools. Through coaching, workers can identify minor issues before they become major problems. Workers can identify error precursors and error traps before having an active error or an event. Injuries can be reduced by providing employees with the knowledge and recognition skills to know when they are operating in a specific error trap and how to escape it using these various tools.

The purpose of in-the-field observations is to review the quality and effectiveness of work preparations, practices and performance. Observations can be performed by both managers and employees. Observation scope should include the total job, not just worker behavior. In-the-field observations by managers or employees look at what error traps employees may be encountering based on signals they are providing (e.g., nonverbal cues that they do not have the knowledge or skills to perform a certain task). Tools are then provided to reduce the potential error. These observations may uncover critical learning that needs to be institutionalized to reduce or eliminate potential errors.

Tool 8: Three-Way Communication

In three-way communication, the sender (worker) states the message, the receiver (probably another worker) acknowledges the sender and repeats the message in a paraphrased form, and the sender acknowledges the receiver's reply. This method can be used to communicate changes to physical facility equipment during work activities via face-to-face, telephone or radio modes of communication. It also is used to ensure that critical steps (e.g., within a safety critical procedure) are being strictly followed. Like the other tools, this one engages workers because they perform it themselves as a communications team.

Tool 9: Concurrent Verification/Peer Checking

Concurrent verification involves a series of actions by two individuals working together at the same time and place to separately confirm the condition of a component before, during and after an action, especially when consequences of an incorrect condition or action would produce great harm. Using this tool, the performer and verifier agree on the action to be taken; they separately self-check the action to be performed; they agree once again; the verifier observes the performer during execution; and the verifier stops the performer if action is incorrect.

Concurrent verification is typically applied to verifying conditions, while peer checking is more oriented toward verifying actions. Peer checking is used to prevent an error by the performer and augments self-checking by the performer. This technique takes advantage of a fresh set of eyes. The performer (worker) self-checks the correct component or hazard present; the peer self-checks the correct component or hazard present; the performer and peer agree on the action; the peer observes the performer before and during execution; the performer executes the intended action; the peer stops the performer if the performer's action is incorrect; if the performer's action is correct, the peer informs the performer of such.

These tools engage workers mentally and physically because they use these tools themselves in tandem or as a team.

Tool 10: Procedure Use, Adherence & Review

To use, follow and review a procedure, workers must first understand its intent and purpose. Workers then follow the procedure as written, step-by-step, with mindfulness and an appraisal orientation. Situational awareness transforms into procedural awareness.

However if the procedure is written incorrectly or cannot be implemented safely, then work is stopped and the procedure is revised before work restarts. Workers are vigilant in terms of assessing a procedure's accuracy, completeness, usability, lack of vagueness and internal consistency. Thus, a major outcome of using this tool is the continual improvement and relevance of procedures by workers engaged in this review and improvement process. Organizations would use this tool for activities associated with the rule-based performance mode.

Many error precursors are procedure related. Common examples include vague work guidance or instructions; need for users to make decisions with no real guidance; users have multiple options for choosing course of actions; users have options to choose next course of action contingent on conditions, which requires the user to determine whether such conditions are present; procedures with multiple actions included in one step; and procedures with embedded actions that could be easily missed.

Another View on Human Performance & Safety Management

This article has posited that workers should be on the defensive against active errors and their precursors in the workplace, which can be achieved by using human performance tools that promote worker engagement. This argument is not being primarily made because workers commit these active errors and, therefore, should be responsible for their control. Rather, workers cannot rely solely on management and management systems to identify and remove error precursors, let alone latent organizational weaknesses that may have led to these error precursors in the first place. Latent system weaknesses are land mines waiting to detonate and workers, unless they adopt their own personal defenses, will be the ones injuried by the proverbial shrapnel.

Since safety can be viewed as the presence of defenses in processes, procedures, facilities, methods and practices (Muschara, 2012), workers must become defensive safety warriors. Workers are in the best position to identify conditions and precursors that could lead to error and, therefore, they should be armed with situational awareness and should be mindful of uneasiness in the workplace. Workers need to be wary and aware of their own vulnerabilities and limitations.

But another practical reason exists for placing workers at the center of error identification/avoidance and performance improvement. Safety management systems are always flawed during their development and implementation. Perhaps this is because such systems cannot anticipate and control all possible work situations (due to economic and

Workers are in the best position to identify conditions and precursors that could lead to error and, therefore, they should be armed with situational awareness and be mindful of uneasiness in the workplace.

practical reasons) or are slow to adapt to changing and variable situations or uncertainty because of their rigid, controlled and complicated structures.

Safety is the ability to perform work in varying and unpredictable work environments (Conklin, 2012). Where work is performed in a constantly changing workplace, workers who are capable of error are implementing flawed safety management systems. Active errors occur at this "sharp" edge, where flawed safety management systems touch potentially flawed workers and potentially flawed workers touch tasks being performed that are shrouded by veils of uncertainty.

The human performance system model of human error posits that events are caused by the totality of the organization contributing to initiating events and failing to contain the results. Another approach is the pessimistic person model of human error which believes that errors and violations originate from the perversity and unreliability of human nature. Both models are probably correct to some extent and the concept of preparing workers to be defensive against unknown latent errors and error precursors caused by the organization as well as potential active errors caused by their own deficiencies combines these two approaches from a pragmatic perspective.

Systems are often not well designed and maintained; designers cannot foresee and anticipate every contingency; procedures may be incomplete or inaccurate; and workers may not behave as they are expected to behave (Conklin, 2012). However, engaged workers are remarkably adaptive and compensating to uncertainty and threats in the workplace—and things *can* go right in light of such uncertainty because of workers' personal defenses and concern for their own well-being. This can be demonstrated by engaged workers successfully using human performance tools to manage both their organizations and themselves, in spite of their organizations and themselves. **PS**

References

Conklin, T. (2012, March 13-14). Events . . . beyond safety-basis. HP Summit, Cleveland, OH.

Cornell, R., Kramme, S. & Snyder, J. (2012, March 13-14). Managing human error in a time critical environment. HP Summit, Cleveland, OH.

Dekker, S. (2006). *The field guide to understanding human error.* Burlington, VT: Ashgate Publishing Co.

Ferguson, B., Ferguson, J. & Barger, D. (2012, March 13-14). Integrating human performance into fatality and incident prevention for improved business results. HP Summit, Cleveland, OH.

Fisher, R. (2012, March 13-14). Integrating human performance concepts into processes, procedures and analysis. HP Summit, Cleveland, OH.

Harter, J.K., Schmidt, F.L. & Hayes, T.L. (2002). Business-unit-level relationship between employee satisfaction, employee engagement and business outcomes: A meta-analysis. *Journal of Applied Psychology, 87*(2), 268-279.

Kahn, W.A. (1990). Psychological conditions of personal engagement and disengagement at work. *Academy of Management Journal, 33*(4), 692-724.

Muschara, T. (2012, March 13-14). Critical steps: Managing the human risks. HP Summit, Cleveland, OH.

Performance Improvement International. (2000). Internal study of errors across the nuclear industry.

Perrow, C. (1984). *Normal accidents. Living with high-risk technologies.* Princeton, NJ: Princeton University Press.

Petersen, D. (1998). *Safety management: A human approach* (3rd ed.). Des Plaines, IL: ASSE.

Reason, J. (1990). *Human error.* Cambridge, U.K.: Cambridge University Press.

Reason, J. (1997). *Managing the risks of organizational accidents.* Burlington, VT: Ashgate Publishing Co.

Shockey, J., Holland, M. & Shelby, L. (2012, March 13-14). Integrating human performance into the path of work for improved business results. HP Summit, Cleveland, OH.

Summers, J.C. (2012, March 13-14). Risk management and risk recognition: Strategies to Improve Performance. HP Summit, Cleveland, OH.

U.S. Department of Energy (DOE). (2009a). *Human performance improvement handbook: Concepts and principles* (Vol. 1; DOE-HDBK-1028-2009). Washington, DC: Author, Technical Standards Program.

U.S. DOE. (2009b). *Human performance improvement handbook: Human performance tools for individuals, work teams and management* (Vol. 2; DOE-HDBK-1028-2009). Washington, DC: Author, Technical Standards Program.

U.S. DOE. (2012). Managing maintenance error: Using human performance improvement. Washington, DC: Author, Human Performance Center. Retrieved from **www.hss.doe.gov/sesa/corporatesafety/hpc/descriptions/MME_H_Handout_Managing_Maint_Error.pdf**

Veazie, M.A., Landen, D.D., Bender, T.R., et al. (1994). Epidemiologic research on the etiology of injuries at work. *Annual Review of Public Health, 15,* 203-221.

Wachter, J.K. & Yorio, P.L. (2012a). *Current practices related to the use of human performance improvement and worker engagement tools.* Manuscript submitted for publication.

Wachter, J.K. & Yorio, P.L. (2012b). *An investigation of safety management system practices and worker engagement on safety performance outcomes.* Manuscript submitted for publication.

Wickens, C.D. (1992). *Engineering psychology and human performance.* Columbus, OH: Charles E. Merrill Publishing Co.

Yorio, P.L. & Wachter, J.K. (2012). *Safety program focused justice perceptions and job distractions as antecedents to safety specific job engagement and occupational near misses.* Manuscript submitted for publication.

Zacharatos, A., Barling, J. & Iverson, R.D. (2005). High-performance work systems and occupational safety. *Journal of Applied Psychology, 90*(1), 77-93.

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