Human Factors

Injuries & the Experienced Worker

"He was too experienced to have done something like that!"

By David G. Curry, Robert D. Quinn, David R. Atkins and Tage C.G. Carlson

WHILE MANY INDUSTRIAL ACCIDENTS involve new workers who often have an inadequate appreciation of the potential dangers in their workplace, a substantial number of these cases involve older, more experienced workers who "should have known better." The potential cause of this apparent paradox is complex, but may have an impact on the nature of both product design and workplace safety training.

When one considers the likelihood of accidents in the industrial sector, the common assumption is that experience and skill are primary factors in their prevention. Some current theories regarding risk-taking behavior suggest that this is not always the case [Naatanen and Summala; Summala; Wilde(a); (b)]. In fact, experience and skill can actually have a negative impact on risk-taking behavior, leading the experienced worker to take chances that a less-experienced worker might avoid.

When discussing the concept of risk homeostasis, Wilde notes "the degree of risk-taking behavior and the magnitude of loss due to accidents and lifestyle dependent disease are maintained over time, unless there is a change in the target level of risk" [Wilde(b)]. This means that, in general, each individual determines an "acceptable" level of subjectively estimated risk for any particular task in exchange for the benefits s/he expects to receive for undertaking the activity and guides his/her behavior based on the balance between the two.

Thus, if the level of risk associated with an activity is assessed as being greater than a person's acceptable level, s/he will likely exercise greater levels of caution than would otherwise be the case. The converse would also be true: If the level of risk is viewed as being less than the acceptable level, an individual will likely engage in actions that increase his/her level of risk-taking. Individuals tend to regulate their behavior in order to maintain a homeostasis (balance) between risk-exposure and risk-avoidance at what they determine to be an acceptable level.

The Experience Factor

The dangerous aspect of this approach is that the risk-exposure level is subjectively, not objectively, determined. Consider the relatively prosaic example of the driver who routinely drives five to 10 mph faster than the speed limit. The benefit associated with such behavior is decreased travel time, while the risk of such behavior is the potential to receive a speeding ticket or to be involved in an accident. A

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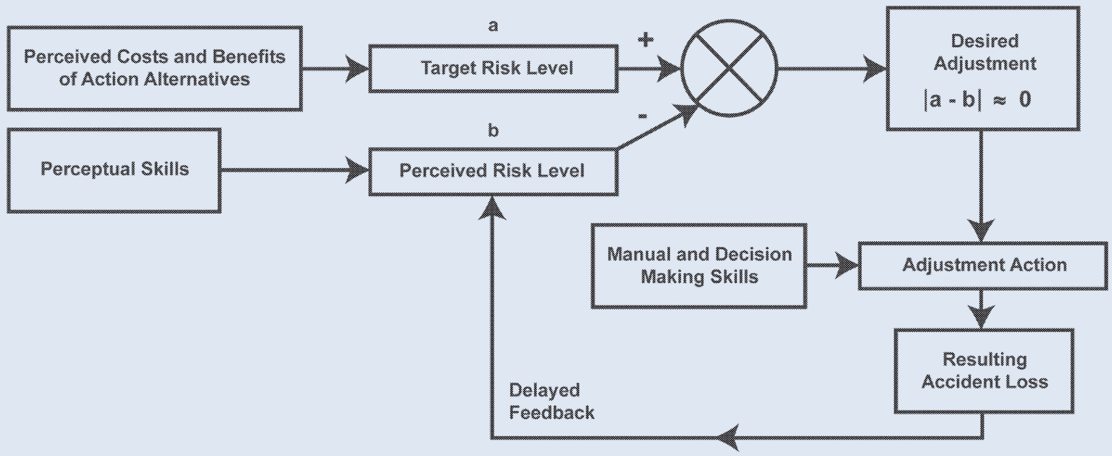
Figure 1
Risk Homeostasis Model



Source: Adapted from Wilde(a).

person may drive for long periods without incurring any penalties while reaping the perceived benefits of speeding. The subjective perception of the risk associated with this action decreases the longer this person drives without being ticketed, potentially leading to even further increases in normal travel speed.

Eventually, however, the person is ticketed or involved in an accident. His/her subjective assessment of the potential risk then increases, normally resulting in a slower driving speed for some period. Objectively, the risk associated with speeding has not changed (indeed, in the extreme short term it may actually decrease, since the location of the traffic control authority for the current area is now known), although a change in risk-taking behavior has resulted. The same type of behavior occurs in the workplace and all other aspects of life. Figure 1 depicts this process.

A similar perspective on risk is provided by the zero-risk theory (Naatanen and Summala; Summala). According to this theory, the perceived risk in a situation is a function of the perceived likelihood of a hazardous event and the importance attached by the individual to the consequences of the event. As self-confidence increases (which occurs as a function of increased experience with the situation), perceived risk diminishes to the point of zero perceived risk.

Under both theories, two variables are critically important when dealing with skilled workers: perceived risk level and perceived skill level. Factors that decrease the perceived level of risk of an activity include familiarity, voluntary exposure, hazard comprehension and the controllability of the hazard. These factors are largely a function of the assessor's level of experience with the hazard. Furthermore, when workers commonly expose themselves to a hazard and experience no harm, a type of "risk habituation" begins to set in, and the perceived level of risk decreases further, while complacency with regard to their capability to successfully perform risky activities increases. For example, experienced drivers routinely overestimate their abilities, with most surveys indicating that drivers rate their capabilities as "above average" while few rate them as "below average."

The inexperienced worker has no basis for judgment regarding the risk associated with a particular behavior—other than prior training. According to product warning research, risk estimates of novice workers will likely be higher than that of their experienced counterparts. Furthermore, the inexperienced worker is less likely to be complacent regarding his/her level of skill in performing a particular task or to intentionally deviate from training. The combination of these factors would be expected to produce a higher degree of risk avoidance behavior among less-experienced workers [DeJoy; Otsubo; Goldhaber and deTurck(a); (b)]. The greater accident frequency of the novice worker may be more a function of insufficient knowledge regarding proper operating procedures or lack of familiarity with them than an intentional nonexecution of those procedures.

By contrast, the experienced worker often has an extensive baseline regarding accident likelihood—both from personally performing the task and as the benefit of past experiences of colleagues. Serious accidents are not common in many of today's workplaces, thanks to regulatory action and safe design practices. Thus, the experienced worker's assessment of the likelihood of experiencing negative consequences from a particular behavior may be far lower than that of less-experienced colleagues. This is particularly true if s/he has successfully performed the action in the past without suffering negative consequences [DeJoy; Goldhaber and deTurck(a); (b)].

Furthermore, the experienced worker is more likely to have an inflated assessment of his/her own level of skill with regard to handling an accident, should it occur, based on the fact that s/he has always successfully avoided consequences in the past. In combination, these factors would be expected to result in increased risk-taking behavior by the experienced worker. The following three examples illustrate these effects in action.

When workers expose themselves to a hazard and experience no harm, a type of "risk habituation" begins to set in, and the perceived level of risk decreases further.

Example 1: Electrical Worker

A journeyman electrician with more than 15 years' experience was set to install a new disconnect on a medium-voltage busway in a large midwestern automobile plant. He was a contract employee and had served successfully in a construction and repair capacity throughout his career. The automaker's facility was state-of-the-art and followed accepted industry safety measures. The journeyman attended regular worker and contractor safety sessions as required by the automaker's management. Violators of accepted safety practices received additional training and were sanctioned for repeated violations. In other words, with regard to both environment and experience, this electrician was a model worker. The last thing anyone would expect is that he would be involved in a careless accident.

The task involved a standard industrial busway of a common configuration: three-phase 480 volts AC overhead, closely spaced copper bus bars covered by a steel shell and providing a nearly infinite supply of current. The busway was the primary power source for the assembly line equipment and robotic welders. Movable disconnects capable of being inserted virtually anywhere along the busway are a central feature of this type of power architecture. The journeyman was to install the new disconnect at an intermediate location along the busway. His first action should have been to take the equipment out of service, then perform a lockout/tagout of the busway's source (the circuit breaker), per established plant safety measures. In this case, however, the source was located in an auxiliary electric equipment room that was remote from the jobsite.

The journeyman's experience alone should have served as motivation to ensure that the equipment was taken out of service before work commenced. Unfortunately, it did not. According to coworker reports, the journeyman told other workers that he would work the busway "hot" and would dispense with ensuring that the lines were de-energized when working with them to "merely" install a simple disconnect. This would save the time and trouble of traveling to a remote location. The journeyman also asserted that he had worked hot equipment before.

In maneuvering the bulky disconnect into position, the main contacts crossed phases. The resulting explosion caused multiple burn injuries and the worker lost time due to incapacitation. Fortunately, he was wearing protective gear, which likely saved his life.

Example 2: Construction Worker

This case involved a worker standing on the roof of a residential structure (with a slope of five inches in 12) while completing the installation of vinyl siding. This worker had been performing such work for nearly eight years and had received continuing training in both appropriate safety procedures and the use of fall protection (e.g., harnesses, lines, slip guards). In this case, the worker decided to forego the use of fall protection (his harness was found on the seat of his truck at the scene) and used a "field expedient" to provide proper footing on the steep roof—he nailed scrap 2x4s through the shingles of the roof rather than install proper slide guards.

During the course of his activities, the 2x4s pulled loose, leading to his fall to a secondary roof then to the ground, resulting in severe injuries. Although well-trained and experienced in appropriate safety procedures and provided with the proper equipment, this worker decided not to use them, believing that his level of skill and experience, combined with shortcuts for proper equipment, would allow him to compensate for the steep roof for the limited time required to complete the job.

Example 3: Boilermaker

A coal-burning boiler was used in a chemical manufacturing facility to generate steam for use in a manufacturing process. The boiler produced exhaust gas that had to be cleaned prior to venting to the atmosphere. This required it to be channeled through a precipitator or "baghouse" that captured the particulates from the exhaust gases. A typical baghouse is designed to allow the exhaust gases to be filtered through a cloth-type bag that retains particulates on the bag's interior. This bag is typically hung vertically from a tube sheet enclosure and is kept from collapsing by using a metal cage on the bag's interior. Periodically, the boiler and baghouse are removed from service to perform maintenance and to allow the bags, cages and waste products to be removed and clean bags to be installed. At that time, the bags are pulled up from enclosures that are approximately two feet below floor covers.

Professional boilermakers normally perform this service. The chemical facility had contracted with a maintenance and repair organization to perform this service during an annual outage. On the first day of the project, the boilermaker involved in this case had worked with the crew removing the insulation blankets, floor covers, venturis and cages in the baghouse. The following day, he entered the baghouse, proceeded along a ledge, then walked across plywood covers fitted to the framework of the removed flooring to the middle of the baghouse in order to reach a stack of cages removed the day before. He then lifted one cage and, rather than retracing his earlier route back to the door, attempted to take a shortcut by walking along the narrow "U" channel that supported the floor covers which had been removed to provide access to the bags. Along the way, he inadvertently stepped off the "U" channel and fell approximately 26 inches to the bottom of the compartment, resulting in a severe ankle injury.

This employee had been a boilermaker for more than 30 years, had completed the union's four-year apprenticeship program, and had worked as both a foreperson and union steward on many sites. He had worked in many similarly designed baghouses at other facilities. As a former foreperson, he had conducted periodic toolbox talks with his crew regarding safe working practices, and as a former union steward, he understood the appropriate actions to take if working conditions were regarded as unsafe.

The facility operator had conducted site-specific training regarding the site's safety program, first-aid facilities, emergency procedures and special safety equipment required before the project began. The maintenance contractor (the boilermaker's employer) also conducted weekly safety awareness toolbox meetings, including one on the topic of hole covers held just seven weeks before this incident. An active disciplinary system regarding unsafe work practices was in place and rigidly enforced by both the plant and the subcontractor.

According to later testimony, despite training to the contrary, the highly experienced boilermaker decided to save a few seconds by taking an unsafe action—attempting to balance both himself and the load he was carrying while walking on a narrow pathway—rather than use the areas prepared for this purpose. This worker judged his level of skill and coordination to be adequate for the task. He weighed the risk involved against the benefit of the time saved and judged, due to his level of skill and experience, that he could handle it. He then purposefully engaged in an unsafe practice.

Implications for Product & Process Design

The implications of the risk homeostasis or zero-risk theories on product design are profound. Given the risk homeostasis theory's assumption that as the perceived level of risk in performing a task decreases, risk-taking behavior increases to maintain the same acceptable level of risk, it would be impossible to increase overall user safety through the design process once foreseeable unintentional interactions with a hazard have been designed out or guarded against. If the product is redesigned to eliminate a potential hazard that results from high-risk user behavior, such behavior becomes acceptable rather than exceptional. Under the zero-risk model, as the employee's perception of the risk associated with an activity drops to zero (or a very low level), the likelihood of the behavior being engaged in increases (or at least the drive to avoid such behaviors drops precipitously).

A good example of this effect at work is mandatory seatbelt laws—effectively the imposition of a guard—now common throughout the U.S. Studies conducted in the Netherlands focused on the effect of seatbelt wearing on driving style. Results showed that when "hard core" nonusers of seatbelts were required to wear them in the experiment, their driving style changed versus that when driving on the same course while not wearing seatbelts.

Among other significant changes in behavior, speed increased, car following distance decreased and braking was initiated later while wearing seatbelts (Janssen). Similar results were found when analyzing the speeds of go-cart drivers on a track while wearing and not wearing seatbelts (Streff and Geller). It is logical to assume that this effect does not apply only to vehicle operations. Many electrical workers routinely risk working with hot wiring, albeit using insulated tools. Would these same workers be willing to expose themselves to this risk were their tools not insulated? Probably not.

One potential consequence of such behaviors are user responses to design changes that are perceived to increase safety, yet may not live up to user expectations. A hypothetical example of this effect would be a two-lane road that is widened to four lanes. Since multilane roads are generally perceived to be safer than two-lane roads, it is not surprising that most such road conversions result in higher traffic speeds once widened. Subsequent analysis of the accident rate on the road in question may show no change or even potentially an increase in accident rate because of driver behavioral changes (i.e., higher speeds).

Another example of this in action is the driver of a four-wheel-drive vehicle who no longer slows down on icy roads. The perceived superiority of the traction available in such vehicles may lead the driver to feel that s/he has adequately compensated for degraded road conditions simply by switching to four-wheel-drive mode.

Unfortunately, the driver is only half right; the four-wheel option allows the driver to steer and accelerate better on slippery surfaces, but it does not improve his/her ability to bring the vehicle to a stop. In this case, the driver has altered his/her behavior in response to a perceived increase in safety provided by an equipment change, without understanding that the actual change in risk exposure does not correspond to the expected change.

Such a theoretical outcome is supported by studies performed in Germany regarding the use of antilock brakes (ABS) within a fleet of cabs (Aschenbrenner and Biehl; Hauer and Garder). After a three-year familiarization and data collection period, it was found that drivers using ABS-equipped vehicles were actually involved in more accidents than those using vehicles without ABS (although the difference did not reach statistical significance). When driver performance metrics were examined, however, it was learned that drivers in ABS-equipped cabs:

- made sharper turns in curves;
- were less able to stay in their own lanes;
- proceeded at a shorter forward sight distance;
- made poorly adjusted merging maneuvers;
- drove faster;
- created more "traffic conflicts" (situations in which one or more vehicles had to take swift action to avoid a collision).

All of these differences were statistically significant. Clearly, the ABS-equipped vehicles were being driven differently than the non-ABS-equipped vehicles; equally clearly, none of these differences were the function of the mechanical aspects of the ABS equipment—all were the result of behavioral changes on the part of the drivers.

Implications for Safety Training

National Safety Council offers this defined order of priority with regard to reducing risk:

1) Design for minimum risk.
2) Incorporate safety devices (guarding).
3) Provide warning devices.

The only effective way that safety can be increased through product design alone is if user behavior does not change as a result. This is unrealistic.

4) Develop standard operating procedures and training programs.

5) Use PPE (Hagan, et al).

Hazards should be addressed at the highest practical level in the hierarchy. If either the risk homeostasis or zero-risk theory is correct, then the first three of these strategies can be of limited effectiveness at best. Reliance on product design alone is ineffective if operators act to maintain a constant level of "acceptable risk" through behavior changes, which in turn negate the positive effects of the design changes. The only effective way that safety can be increased through product design alone is if user behavior does not change as a result (i.e., the changes are unknown to the user). This is unrealistic—protective measures and mechanisms are rarely invisible.

Furthermore, the National Electrical Safety Code defines "guarded" as something that serves to "limit the likelihood, under normal conditions, of dangerous approach or accidental contact by persons or objects" (IEEE). It is difficult to see how such an approach could be more than temporarily effective when "normal conditions" would be altered as a result of changes in operator behavior stemming from the presence of such devices.

Finally, the purpose of a warning is to inform those exposed to a hazard about the nature of that hazard and its potential consequences. In many cases in the working environment, the individual already has such knowledge (particularly those with high levels of experience). Even then, the use of such warnings is only appropriate when "the danger is not one which is obvious, known or readily discoverable by the user"—another condition that may only rarely apply in the case of the experienced worker (Bresnahan, et al).

Conclusion

Taking a more realistic approach, the only truly viable long-term strategy for increasing workplace safety lies in combining normal safe design, guarding and warning strategies with the fostering of an increased understanding among workers of the actual risk involved in their activities. The latter can only be accomplished by the employer—the tool, equipment or machine designer/manufacturer cannot effectively know how their product will be used within a particular work environment.

Thus, safety training must be designed to emphasize the specific consequences of unsafe actions, thereby raising workers' consciousness regarding the potential risks to which they are exposing themselves. Other viable alternatives would be increasing the potential cost of risk-taking behaviors, even if no accidents result (e.g., increased application and enforcement of penalties for violations of safe practices) or the incentivization of safe working practices. While neither traditional education nor safety policy enforcement approaches can address overestimation of personal skill, increased focus on this issue should help reduce the underestimation of potential adverse consequences and increase the perceived costs of risk taking.

According to the risk-taking models presented, accidents cannot be reduced solely through design revisions or increased guarding of the apparatus involved. Such an approach ignores the fact that as the design of a machine evolves so does the behavior of its operators. Focusing solely on design in such cases only results in an endless cycle of safety-related design refinements that may then have their effects negated by changes in the operator's risk-taking behavior. A more balanced approach is required, under which design improvements are accompanied by increased levels of worker training on the nature, likelihood and potential consequences of risk-taking behavior. ■

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