THE ILLUSION OF ATTENTION: Are There "Gorillas" in Your Plant?

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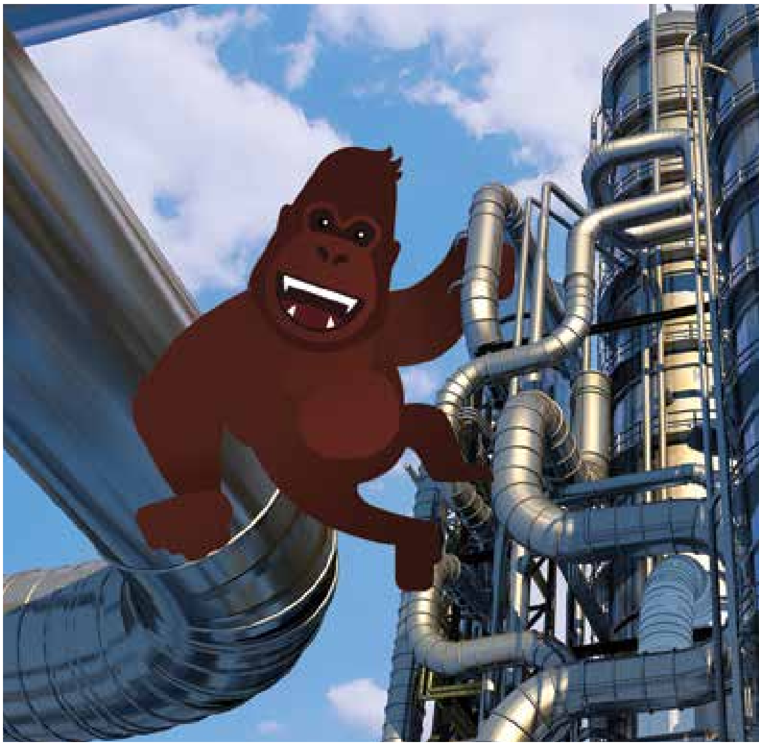
Focusing too much of our attention in a particular area can cause us to miss the obvious. Simply being aware of the phenomenon of inattentional blindness is an important first step toward reducing its effects.

The ability to recognize hazardous conditions is essential to managing risk. However, considerable research in the cognitive sciences has shown that our ability to observe our surroundings is limited by attentional resources. The failure to notice an unexpected stimulus in your field of vision while performing other attention-demanding tasks is a cognitive phenomenon known as inattentional blindness *(1)*.

The best-known study demonstrating inattentional blindness is the "invisible gorilla" experiment *(2)*, which asked participants to watch a video of people passing a basketball and count the number of times the basketball is passed to each participant. In the video, a person dressed in a gorilla costume walks through the scene where the people are passing the ball (Figure 1). After watching the video, participants are asked if they saw anything out of the ordinary. About half of them did not report seeing the gorilla.

The invisible gorilla experiment illustrates the failure in our cognitive ability to notice an unexpected stimulus in our field of vision. The illusion of attention is even more pervasive as it extends to memory and the gaps between what we think we remember and what we actually do remember.

This article presents evidence obtained through an established process-hazard-identification program that inattentional blindness is a near and present danger. This evidence is consistent with the results of the invisible gorilla experiment, and suggests that our ability to recognize hazards can be impaired more than we think. The article then provides a proactive model for organizational management of change (OMOC) that addresses this phenomenon by seeking an optimal level of awareness. Recognizing



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that awareness is largely a function of training, knowledge, competency, and culture, the model balances experiential knowledge against the detrimental effects of emergent inattentional blindness. This approach can enable improvements in conduct of operations and operational discipline.

The illusion of attention

Most of us have experienced a situation like this: You're driving to your next engagement after a particularly challenging day at work and your thoughts begin to wander. An employee at your manufacturing site has been injured due to an unrecognized hazard. The safety manager asked you to participate in the incident investigation, document the contributing factors, and share the learnings with the organization. You reflect on how, over the past two years, company safety performance metrics have steadily improved toward the goal of zero injuries, with very few incidents during this period — and you are disappointed about the broken streak without a lost-time injury.

As you are driving, your mind has wandered — contemplating whether this incident was due to poor decision-making on the part of the employee or a cascade of highly unlikely circumstances. In the course of this reflection, your attention has shifted from driving a two-ton motor vehicle at 60 miles per hour, to recollecting incident statistics and brainstorming solutions to prevent future incidents. The vehicle has traveled more than a mile, passing several exits and numerous other vehicles. Your attention on the road has been hijacked by your thoughts.

▲ **Figure 1.** In a 1999 experiment, subjects were asked to watch a video of students passing a basketball and count the number of times the ball changed hands. Half of the viewers failed to notice the gorilla who strolled through the proceedings *(2)*. View the video and learn more at www.theinvisiblegorilla.com. Image courtesy of Daniel Simons.

This scenario can be understood in terms of the phenomenon of inattentional blindness. Any task that places a high demand on our attention can take away from our ability to recognize rare, unexpected, and potentially hazardous or catastrophic situations. Consider trying to multitask while listening in on a conference call and working on the computer. We cannot apply the same level of attention to both tasks because the mind's capacity to execute these tasks is limited. Why should concentrating intently on a specific task and driving be any different? It's not, and cognitive scientists have reproduced these effects in controlled laboratory experiments *(3)*. In fact, the illusion of attention extends beyond visual perception; it's observed in hearing, memory, and even knowledge *(4)*.

The existence of these limitations on our ability to process information about our surroundings has important implications on process safety programs in the chemical process industries (CPI). Many companies have implemented process safety and risk-management programs to comply with regulations and reduce risk to stakeholders. These include a broad range of programs that address facilities, technology, and people. Hazard-identification and risk-assessment programs frequently strive to develop employee competency in order to increase knowledge and awareness of hazards in the workplace. While important, these programs often do not explicitly address the cognitive aspects of operational discipline. Given that injuries and incidents with catastrophic consequences continue to occur, it is apparent that a gap exists in our current understanding of the importance that cognitive science plays in conduct of operations and operational discipline.

Although it might seem counterintuitive, highly focused attention may detract from our ability to see the unexpected. Focusing too much of our attentional resources in a particular area can lead us to miss the obvious.

Inattentional blindness

Research performed at Harvard Medical School found inattentional blindness among participants with expertise in a subject similar to that of a naïve observer performing an unfamiliar task *(5)*. That study asked 24 radiologists to review radiological lung scans and detect any nodules present. The last scan contained an image of a gorilla that was 48 times the size of the average nodule. Eighty-three percent (83%) of the radiologists did not see the gorilla. Furthermore, eye tracking revealed that the majority of participants who missed the gorilla had looked directly at its location.

In order to see, one must look; but merely looking is

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not sufficient for seeing. This is apparent in motorcycle safety statistics. Intuitively, it would seem that reflective and brightly colored clothing would help make the motorcyclist stand out. However, many motorcyclists are not seen precisely because, even though they do stand out, they are unexpected. A study conducted in several California cities and European countries revealed that walking and biking were the least dangerous in the cities where these activities were done the most, and the most dangerous where they were done the least *(6)*. This suggests that when people are conditioned to look for a particular stimulus (*e.g.*, a motorcyclist), they are more likely to notice the activity.

The implications for process safety are significant. In any organization, invisible "gorillas" lurking in our midst have the potential to cause damage. Whether lingering in an operating unit, in process safety documentation, or in routine operating and maintenance tasks, the tendency to not recognize obvious warning signs is prevalent.

The Center for Chemical Process Safety (CCPS) book *Recognizing Catastrophic Incident Warning Signs in the Process Industries (7)* discusses warnings signs that are often overlooked before serious incidents. Excessive focus on operating costs, production targets, and product quality can obstruct our ability to focus on leading indicators of compromised process safety systems. Andrew Hopkins, a safety expert and professor of sociology at Australian National Univ., goes even further to suggest that such warning signs are often disregarded: "Prior to any major accident there are always warning signs which, had they been responded to, would have averted the incident. But they weren't. They were ignored. Very often there is a whole culture of denial operating to suppress these warning signs" *(7)*.

Focusing on a specific objective takes away from our ability to notice the unexpected. We reliably observe the onset of things like cost overruns, dissatisfied customers, and production shortages, and we react. However, signs leading up to catastrophic outcomes are more subtle. Furthermore, employees tend to not recognize or give credibility to the patterns because in many cases they have not experienced these events firsthand.

Understanding the nature of inattentional blindness can explain why warning signs are not always recognized. In other words, failing to acknowledge a warning sign may not be due to conscious decision-making (seeing and not reacting), but rather due to an unconscious lack of awareness (looking and not seeing). The lack of awareness and an organization's inability to collectively act on the warning signs contribute to catastrophic outcomes. The organization is constrained in a state where process hazards, safety system impairments, and unrevealed failures go unrecognized.

Unfortunately, there is little evidence that differences in people's attention capacity or expertise influence their ability to recognize the unexpected. In fact, inattentional blindness is not always a problem; it is a result of our unique ability to focus our mind. Despite the challenges it poses, simply being aware of the phenomenon is an important first step toward reducing its effects. Furthermore, an organizational culture that is open to unconventional methods of identifying and managing hazards can enable employees to recognize patterns that would otherwise go unnoticed.

It is with this mindset that we undertook an investigation to determine the effects of inattentional blindness in order to increase employee knowledge and organizational support for process safety.

Spot the hazard

"Spot the Hazard" is a monthly contest that challenges employees to recognize process hazards. A photograph of an actual hazardous situation is distributed electronically to all plant personnel, and the members of the process safety department review submissions to identify correct responses. This program is an effective educational tool that increases employees' hazard awareness, and supplements other programs and initiatives to foster process safety culture in an organization *(8)*.

For one investigation, we obtained a photo from an external source that showed a decommissioned storage tank with severe degradation to its insulation and structural supports. The most unusual hazard associated with the picture was that a grizzly bear had accessed the tank farm and made its way to the top of the vessel. The bear was conspicuously perched on the roof, stooped over near the relief device.

Akin to the Harvard researchers inserting a gorilla into an X-ray image, we added a fabricated image of a bear to the photo near the bottom of the storage tank. We expected that the real bear on top of the tank would be obvious and the fabricated bear image would be observed to a lesser degree. We received 180 responses from nine manufacturing facilities. Surprisingly, 44 (24%) of the respondents completely failed to recognize the bear on the tank, while 175 (97%) of the respondents failed to notice the fabricated bear image near the bottom. Perhaps even more interesting, many responses that did not mention the two unexpected hazards (*i.e.*, bear images) contained extremely detailed observations with respect to the poor conditions of the tank. This clearly demonstrates that operations personnel are not immune to inattentional blindness.

Management of change (MOC)

Effective, proactive organizational management of change can increase the ability of employees to recognize unexpected hazards. In order to maintain operational discipline, change must be managed at a rate appropriate to effectively maintain knowledge, commitment, and awareness. Too much change in an organization can cause knowledge attrition and inefficiency. Too little change can result in normalization of deviance (NOD) and complacency.

Consider an organization that has not experienced a significant incident within the collective memory of its workers. This lack of incident history can create a culture whereby employees fall into the trap of doing things the way they have always been done. Furthermore, employees likely will not possess the desired sense of vulnerability that is otherwise instilled in individuals who have experienced irreversible consequences firsthand. Yet, over time, as the manufacturing process undergoes subtle changes in its operating and maintenance practices, the facility may experience risk creep and a gradual rise in change blindness. This increasing risk can go completely unnoticed.

CCPS's book *Guidelines for Management of Change for Process Safety (9)* identifies the key principles and essential features of MOC systems. One of these essential features is the identification of potential change situations. In order to evaluate the risk of a change, the potential change itself must first be recognized. MOC workflow diagrams typically recognize this with "identify the need for change" as the first step of the MOC process.

This implies that MOC is generally prompted in response to another action. Examples of actions that may give rise to the need for MOC are capital project proposals, remedial responses to process-related incidents, and newly promulgated codes and regulations that require a facility modification. As a result, MOC has traditionally been regarded as reactive in nature. However, the potentially detrimental effects of inattentional blindness make it important for process safety management (PSM) programs, in particular MOC programs, to proactively address this issue.

Cross-pollination

Employee complacency and normalization of deviance are potential risks to an organization when too little change occurs. Placed in the context of roles and responsibilities, complacency may develop and grow in an organization that allows departmental silos to be created. Silos will almost certainly create artificial barriers at the unit, plant, and corporate levels that inhibit the exchange of ideas and the sharing of knowledge that are broadly beneficial to process safety management programs. In recognition of this, it is common practice to use an outside third party to facilitate process hazard analyses (PHAs) as a means of combating inattentional blindness.

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Similarly, the practice of using employees from other units or plants as third parties in a PHA study, commonly referred to as cross-pollination, can be an equally effective strategy. Cross-pollination can also be applied to other traditional process safety activities, such as compliance audits, incident investigations, and pre-startup safety reviews. When this is done in a purposeful manner, the organization benefits from the perspectives and knowledge introduced by the diverse group of participants.

Consider the pre-startup safety reviews (PSSRs) that are conducted near the end of construction activities prior to startup (which for a large project with a construction phase of a year or more may take several weeks). Given the importance of the PSSR to the operational safety of the project, it is prudent for organizations to explicitly address team diversity in their corporate engineering standards, for example, with a statement such as: "Commensurate with the scope, novelty and complexity of the project, the audit team shall include personnel that were not directly involved with the project" *(10)*. In this way, cross-pollination becomes a mandatory expectation of PSSRs.

Facility inspections, also known as planned general inspections (PGIs), deserve special mention because they are a vital component of a comprehensive PSM program. PGIs are conducted in an organized, planned, and recurring fashion. They are, in short, process hazard reviews taken to the field, whereby plant personnel spend 1–2 hours surveying a portion of an operating unit for both process and occupational hazards. A PGI is an excellent opportunity to identify gorillas in a plant.

Many factors can significantly hinder the effectiveness of PGIs, and PGIs that are not conducted properly may fail to address less-obvious concerns *(11)*. Plant personnel are inclined to miss the gorillas in their own plant. Therefore, PGIs should be conducted by cross-pollinated, multidisciplinary teams. Through cross-pollination, the hazards that have been previously overlooked through inattentional blindness are more likely to be identified and addressed.

A new model for proactive organizational management of change (OMOC)

We propose that personnel awareness with respect to hazard identification can be illustrated by the Weibull probability-distribution function and the U-shaped bathtub curve (Figure 2). The nuclear power industry has used human cognitive reliability models based on the Weibull distribution to model task execution by plant operators in accident scenarios *(12)*. The bathtub curve has been used to illustrate the concept of error states in human systems and the progression of an accident through phases as a function of increasing employee experience *(13)*. Thus, we can use the time-variant model illustrated in Figure 2 to represent organizational hazard awareness.

In the current model, hazards that are visible to the individual are considered opportunities to identify a hazard; in other words, they are demands placed upon the individual's awareness. The average rate of failure to observe a given hazardous condition is represented by the failure rate (lambda, λ) specified in the Weibull distribution function (Figure 3).

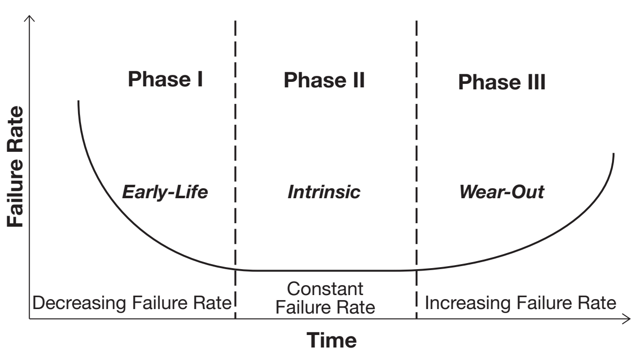
In Phase I (*i.e.*, the learning curve phase), as an employee is indoctrinated into a new role or organization, he or she must navigate a learning curve, acquiring the knowledge and skills needed to effectively recognize unexpected hazards. Over time, as the individual acclimates to the work conditions, processes, and culture, the observation failure rate declines. In Phase II (*i.e.*, the competent phase), the observation failure rate is lowest, and optimal hazard awareness is achieved. In Phase III (*i.e.*, the complacency and normalization of deviance phase), abnormal and hazardous conditions are more readily accepted by employees, leading to an increased failure rate and a decline in the employee's ability to recognize hazards. Thus, personnel awareness can be characterized by three phases in terms of an individual's ability to recognize hazards (Figure 3):

- learning (decreasing failure rate)
- competence (low failure rate)
- complacency and normalization of deviance (increasing failure rate).

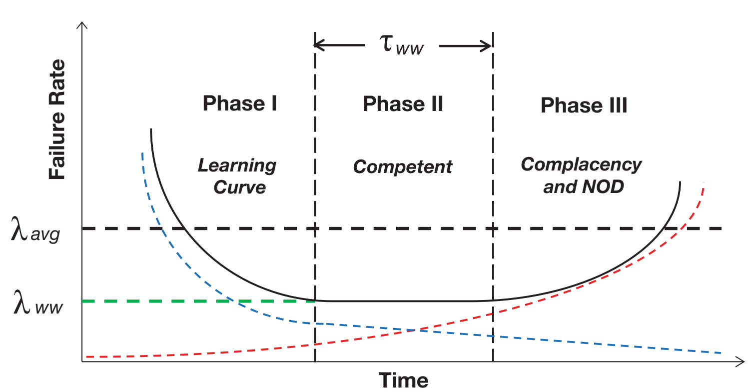
If OMOC is implemented proactively, continuing education and synergies among plants and units can shorten the duration of the learning phase. Similarly, the complacency phase can be diminished in magnitude by changing employees' roles and responsibilities in a deliberate manner. Thus, through proactive OMOC, an organization can influence the shape of the bathtub curve, for instance, by transitioning individuals through positions at time intervals that achieve a minimum average failure rate across the entire organization.

The minimum failure rate for the overall population is denoted λ_{ww}, and the optimal time interval to maintain a minimal rate of failure is introduced in the current model as the Wolf-Wasileski interval parameter, τ_{ww}. This optimal time interval occurs in the minimum region of the bathtub curve, which is actually composed of two separate curves for early-life and wear-out behavior. The early-life and wear-out curves may be asymmetric, and the minimum (and τ_{ww}) may not occur at the intersection of the two individual curves.

In Figure 3, τ_{ww} is shown as a range that spans the minimum value of the bathtub curve. It is important to recognize that the optimal time interval is likely to be different depending on the characteristics of the organization and the individual unit operation. Unit operations that are highly complex and inherently high-risk typically require a longer time to enter the τ_{ww} region than a simple low-risk operation. Consequently, a large-scale petroleum refining operation would be expected to exhibit a τ_{ww} time interval parameter that is shifted to the right on Figure 3, whereas



▲ **Figure 2.** The Weibull distribution can be applied to mechanical component reliability, biology, weather, finance, and a broad range of other systems that obey the characteristics of the bathtub curve. Early in the lifecycle, component failure rates decrease (Phase I), eventually leveling off and remaining relatively constant (Phase II). As the system approaches the end of its life (Phase III), components begin to wear out, and the failure rate increases again.



▶ **Figure 3.** The bathtub curve can be applied to the failure rate associated with an individual's ability to recognize hazards. The overall curve can be divided into separate curves that represent a decreasing failure rate (blue) and an increasing failure rate (red). Early in the lifecycle, people acquire knowledge and learn to identify hazards (Phase I), eventually reaching a level of competence (Phase II). As time progresses, normalization of deviance (NOD) and complacency begin to set in (Phase III). The target state is to achieve a minimal failure rate and optimal level of awareness over a time interval represented by τ_{ww}.

the competency phase for a simple and inherently low-risk operation, such as a packaging operation or in a warehouse facility, would be shifted further to the left.

This conceptual framework suggests that an organization can achieve an optimal level of awareness by managing the rate of organizational change (*e.g.*, Wolf-Wasileski interval parameter) at the organization, facility, and/or process unit levels. The optimal interval depends on an organization's size and dynamics, so a universal interval is not recommended. However, companies should establish a specific target interval through proactive OMOC to maintain optimal hazard awareness.

Closing thoughts

An organization's management must recognize that inattentional blindness is a near and present danger in the CPI, and that even subject-matter experts operating in their field of expertise are vulnerable to it.

In practice, the concepts discussed here can be institutionalized through corporate policies, standards, and procedures. In this way, OMOC becomes a proactive, rather than reactive, activity. Extended further, proactive OMOC can include rotating certain roles or responsibilities on a predetermined frequency. For example, in petrochemical complexes, it is common for engineers to serve three- to five-year terms on one process unit, and then rotate to another process unit within the complex for a second term, and so on. While this practice clearly expands the engineer's experience, it also provides a greater benefit to the organization at large because it fosters a culture of knowledge exchange and continuous improvement, which generally improve the quality of inspections, reviews, and other PSM activities. It is, therefore, imperative that organizations routinely practice some form of role rotation, particularly at the plant level.

We are currently investigating a methodology that allows facilities to quantify the Wolf-Wasileski interval parameter, τ_{ww}, for specific situations. CEP

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