Seeing *versus* Perceiving

What you see isn't always what you get

By David G. Curry, John E. Meyer and John M. McKinney

A SEEMINGLY CRITICAL QUESTION with regard to investigating an accident or in any subsequent litigation is, "Was it visible?"—where "it" refers to whatever object could have been noticed in order to mitigate or prevent the subject accident (e.g., smoke, a stopped automobile, a pedestrian). While this question has some merit, a more crucial question in most cases is, "Would it be *perceived*?" Most people would say that the two questions are equivalent and that "seeing" and "perceiving" are synonymous. Such is not the case.

Sensation versus Perception

Sensation refers to the immediate response of a person's sensory receptors (e.g., eyes, ears, nose, mouth, fingers) to basic stimuli such as light, color, shape or sound. *Perception* is the process by which sensations are selected, organized and interpreted. As William James, the father of psychology in America, said, "Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our own mind" (James).

Many people incorrectly regard perception as a passive process in which the mind records the data that the senses gather. In reality, perception is an active process; it "creates" rather than "records" reality based on the individual's understanding of the stimuli to which s/he attends. As such, perception is strongly influenced by factors such as an individual's experience, education and cultural values to interpret the input received by the body's sensory receptors. Individuals can process only a small amount of the sensory information available to them; an even smaller amount is attended to and, therefore, given meaning. Again, in the words of James, "My experience is what I agree to attend to." This perceptual process is depicted in Figure 1.

The critical difference between sensing and perceiving lies in the concept of attention—that is, the extent to which mental processing activity is paid to a particular stimulus. A good illustration of this is the *Where's Waldo?* book series for children. In these books, the character Waldo is perceptually "hidden" within an extremely busy visual scene and the challenge is to find him within the picture—and this can often be extremely difficult. Because of the amount of visual clutter on the page, a person does not know where to focus attention within the picture or how to filter out the extraneous information. As a result, a person is virtually overwhelmed with data and Waldo simply does not stand out from the background.

Once Waldo is finally located, however, during subsequent references to the same image a person knows where to focus visual attention and Waldo seems to jump out from the background imagery. Similarly, in the real world, there is nothing that distinguishes the critical object within a visual scene from its background and, thus, the object is not attended to or perceived at first glance, although it may be extremely noticeable once its presence is detected.

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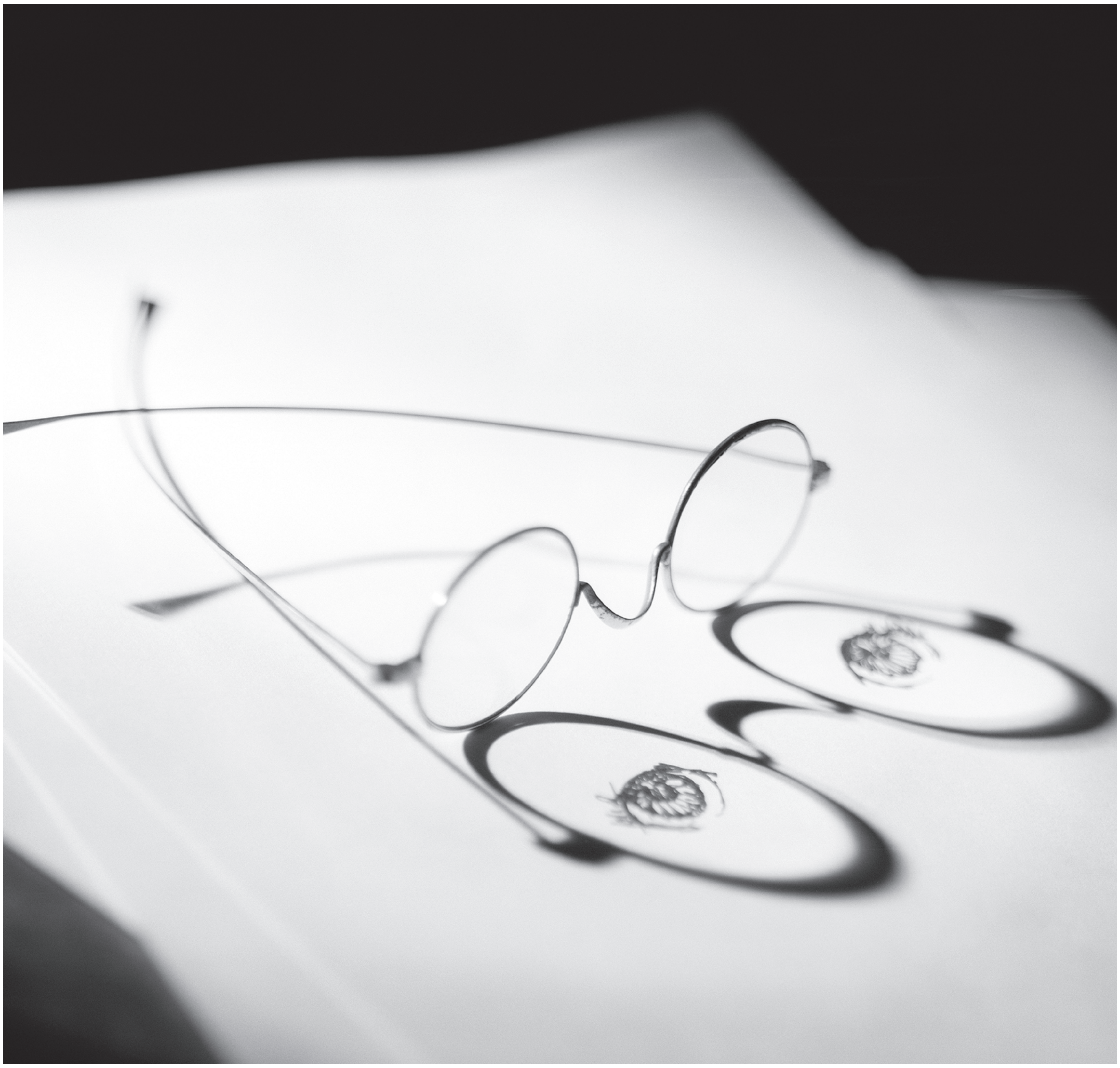

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Abstract: *In many accident cases, the information necessary to successfully avoid the mishap was readily available to the victim who, for some reason, either did not notice or attend to it. Even when critical information is open and obvious, focus on other aspects of the task being performed or the assumption that no hazards exist can lead to accidents that reasonable attentiveness could have readily prevented. This article addresses the considerable difference between sensing and actually perceiving potential hazards in the work environment; introduces the concept of inattentional blindness; and presents five case studies involving accidents that could have readily been prevented had the participants been more aware of their environment and adopted less of a "business as usual" mindset. Recommendations regarding increasing awareness of the potential for such accidents are also provided.*

Anyone who has ever had an audiogram performed is familiar with the "ghost sound" phenomenon, in which the person is unsure whether s/he has actually been exposed to a stimuli and, therefore, does not know whether a response is appropriate. The likelihood of responding to or having one's attention caught by a similar sound (in terms of both intensity and frequency) in the real world would be virtually nil, although this does not imply that a person could not detect the stimuli if s/he were to be sensitized to it (e.g., just because a person can hear the ticking of a watch when listening to it does not mean s/he will normally notice it during the course of daily activities). The same phenomenon is true with other senses as well. The detection threshold for an object of which the observer is unaware is often twice or more what it would be for an object whose presence is known and for which the observer is actively searching (Olson and Farber).

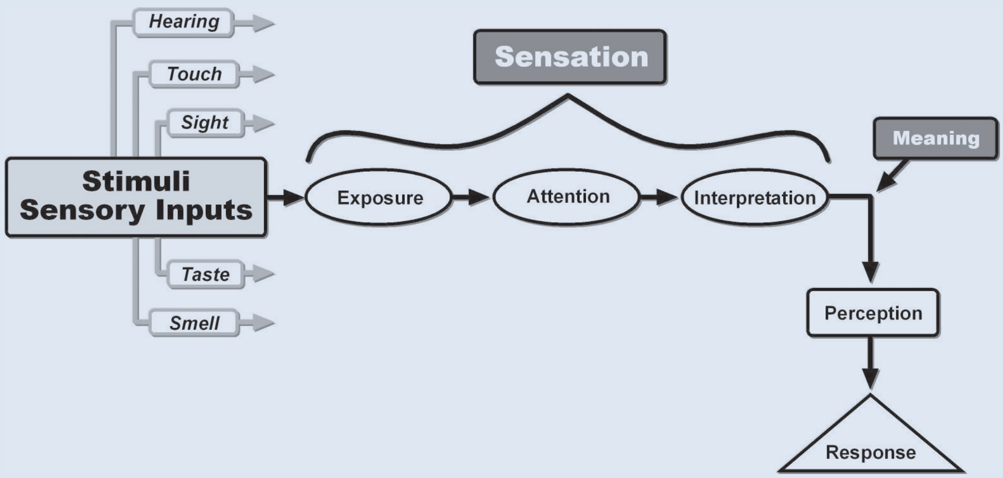
Knowledge of the presence of an object is often critical to the likelihood that it will be detected as well as that it will be correctly interpreted. People tend to perceive what they expect to perceive; a corollary to this is that it normally requires a greater amount of unambiguous information to recognize unexpected phenomena than expected ones. Such expectations stem from a range of sources—including education and training, past experience and cultural norms—and may vary with circumstances. These expectations, or perceptual sets, tell a person what to look for and what is important, and guide him/her on how that which is sensed should be interpreted (Heuer). Such expectations are unavoidable and represent the only way to deal with the sheer volume of complex data that constantly bombard a person's sensory receptors.

An important characteristic of such expectations is that they are relatively quick to form, but highly resistant to change. New information is assimilated and interpreted in light of pre-existing expectations, rather than being evaluated in isolation. This often results in gradual or evolutionary change being unnoticed ("change blindness") and "the more ambiguous the information, the more confident the actor is of the validity of his image, and the greater his commitment to the established view" (Jervis). Even more striking is the fact that exposure to ambiguous stimuli often interferes with accurate perception—even after better information becomes available.

Bruner and Potter illustrated this point by showing subjects images of common objects that were blurred to varying degrees, then gradually sharpened until subjects reported being able to correctly identify them. Results showed that the greater the initial degree of blur, the clearer the picture had to become for subjects to recognize the objects, and that the longer the subjects were exposed to the initial blurred image, the longer it took them to correctly interpret it. Bruner and Potter theorized that this

Figure 1

The Perceptual Process



Note. *Based on material from* The Psychology of Intelligence Analysis, *by Richard J. Heuer Jr., 1999. Washington, DC: Center for the Study of Intelligence, Central Intelligence Agency.*

was caused by the subjects forming tentative hypotheses regarding the nature of the image; until sufficient information became available to disconfirm this hypothesis, the original interpretation of the data was retained. In practice, the amount of information required to make an initial hypothesis is much lower than that required to invalidate it, so the initial interpretation was retained for longer than would be the case had the less-blurred image been presented earlier in the study (Bruner and Potter).

Adding to the complexity of stimulus interpretation is the concept of inattentional blindness. This term refers to the tendency for the attention of an observer to become so focused on particular aspects of the visual scene that even highly significant features of the scene may be completely filtered out or ignored (Mack and Rock).

In one experiment, subjects were tasked with viewing a 75-second video clip involving two teams of players passing a basketball among themselves while mentally keeping track of the number of chest versus bounce passes made by members of their assigned team (Simons and Chabris). Midway through the clip, a woman dressed in a gorilla costume walked through the center of the screen over a period of 5 seconds. Results from questionnaires completed immediately after the conclusion of the tape showed that more than 75% of the subjects did not notice the extraneous event. The authors concluded that the likelihood of noticing such an unexpected object depended on the similarity of the object to other objects in the visual scene and how intensely the subject's concentration was focused on other aspects of that scene (Simons and Chabris). Other studies have reached similar conclusions (Neisser and Becklin; Neisser).

Visual Acuity

It is generally agreed that the typical visual field for humans is approximately 175º to 180º horizontally and 120º vertically. However, various factors are not generally appreciated, such as the fact that the lateral visual field declines with age after approximately age 30 to 35 (dropping to approximately 140º by age 80); that the area of binocular overlap between the eyes is only about 60º; and that the portions of the visual field in which colors are perceivable are both nonuniform and drastically smaller than the field as a whole (Boff and Lincoln).

Furthermore, Rantanen and Goldberg showed that the mean area of visual field is workload dependent, being reduced to 92% under medium workload conditions and to 86% under heavy workload. Under both conditions, the reduction in field size was nonuniform, with the medium and higher workload conditions resulting in significant shape distortions when compared to the lighter load condition (Rantanen and Goldberg).

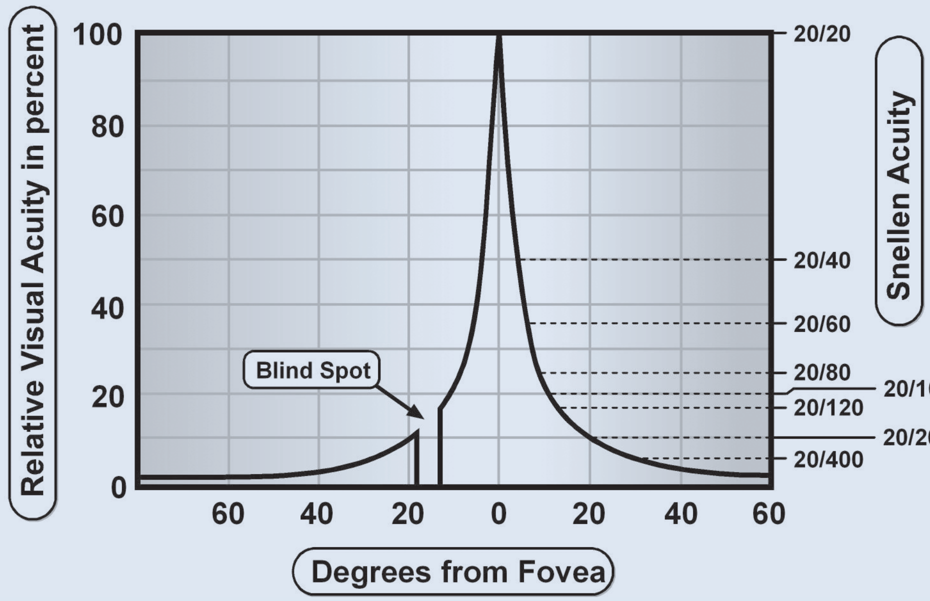
Even more critical is the fact that visual acuity within the field is nonuniform and drops off drastically once the image moves away from the eye's point of visual focus (the fovea). Figure 2 illustrates the visual acuity with optimal lighting at different angles off-axis from the fixation point. As shown, the minimum angle that can be resolved increases by approximately a factor of 5 when the target is shifted only 10º from the fixation point (a visual acuity difference decreasing from about 20/20 to 20/100). By the time the 20º point off-axis is reached, a 10-fold decrease in visual acuity is encountered, lowering visual acuity to approximately the 20/200 level (which is legally blind in most states). Moving progressively further out from the line of focus can reduce the effective visual acuity to as little as 20/800 or less.

Another critical issue is contrast, both in terms of color and brightness. As noted, the eye's color sensitivity is neither uniform across the visual field (Figure 3) nor across the color spectrum. Although large color differences may be present between an object of interest and its background, depending on the target's color and location in the visual field, this difference may not be noticed unless it is within the color detection envelope of the eye or the stimulus somehow captures the observer's visual attention, causing the fixation point to be shifted to it.

Luminance, or brightness, contrast is another issue that is often not addressed in visibility assessments. The ability of the eye to discern a target is often a function of the brightness differential between the target and its background. Targets with lower relative contrast levels with reference to their background require commensurately greater levels of illumination to be detected equally well, and the required degree of difference varies widely depending on the observer's age. Color and hue discrimination also require relatively high brightness levels. This phenomenon is familiar to anyone who has ever tried to identify clothing colors within a dimly lit room—such as when trying to determine whether a pair of socks are navy blue or black, only to discover in bright daylight that what had appeared to be one color was not actually so.

Figure 2

Visual Acuity by Distance from Visual Axis



Note. *Based on data from* Human Factors Design Handbook, *2nd ed., by W.E. Woodson, B. Tillman and P. Tillman, 1992. New York: McGraw-Hill Inc.; and* Engineering Data Compendium: Human Perception and Performance, *by R.K. Boff and J.E. Lincoln, 1988. Wright-Patterson AFB, OH: Harry G. Armstrong Aerospace Medical Research Laboratory.*

Case Studies

Since it may be difficult to see how these factors interact in the real world, the following case studies provide real examples of these concepts at work.

Case Study 1: Roadway Crash

One morning near dawn during a winter month in a southern state, the driver of a small pickup truck was proceeding on his way to work. Approaching a curve in the road, and unbeknownst to the driver, water had seeped through a crack in the road throughout the night and had turned to ice in the cold temperatures. As the truck encountered the patch of ice, the driver lost control of the vehicle, which struck the curb; he hit the roof of his vehicle, suffering a severe neck injury.

Those critical of the driver's actions noted that the ice on the roadway, while unexpected, could have been seen by the driver in time to avoid it. While it may be true that the driver could have detected the ice (had he been aware of its presence), several factors would have reduced the likelihood of him doing so in time to take effective countermeasures. First, the accident occurred slightly before sunrise, forcing the driver to rely on the illumination provided by his headlights. Under nighttime driving conditions, driver visual behavior changes somewhat in comparison with normal daylight driving. During times of full illumination, drivers focus their attention about 2.5 to 3.5 seconds in front of their vehicle, which normally provides adequate time to react and respond to roadway events ahead of them (Hills).

Under nighttime conditions, however, the illumination provided at that distance is greatly reduced for most obstacles or objects in or on the roadway. Drivers respond by focusing their attention closer to their vehicles on the roadway surface in the region directly illuminated by their headlamps (Olson, et al). Indeed, it can be demonstrated based on detection distances for objects such as pedestrians wearing other than white or retroreflective clothing, nighttime speeds exceeding 15 to 20 mph while using low-beam illumination result in the driver "overdriving their headlights" (Wood, et al).

In this case, the driver's task was made even more difficult by both the low contrast between the bare roadway and the patch of ice and the small visual angle presented by the ice (that is, the patch of ice was flat and conformal to the roadway and did not rise substantially above the roadway's surface). At night, objects such as vehicles at other than short distances are normally detected based on the driver's observation of the other vehicle's headlights rather than by the other vehicle being directly illuminated by the driver's own vehicle. Finally, illumination provided by headlights (or any other type of light) does not decrease in a linear fashion with distance; rather illumination decreases with the square of the distance from the illuminating source (e.g., for any given situation, the light falling on an object twice as far away is reduced to one-quarter—not one-half—of that at the original distance).

Exactly where the driver's visual attention was focused laterally across the roadway is another pertinent issue. In this case, while the water originated in the center of the roadway, the domed nature of the roadway caused it to travel toward the outer edge before it froze, creating an obstacle in the center of the lane of travel. Studies have shown that during curve negotiation, the focus of a driver's visual attention changes markedly from that while traversing a normal straight roadway (Olson, et al; Cohen and Studach; Shinar, et al). Much more attention is focused on the inside radius of the curve to the detriment of the center of the roadway. Furthermore, this change in visual focus begins several seconds before the vehicle enters the curve itself.

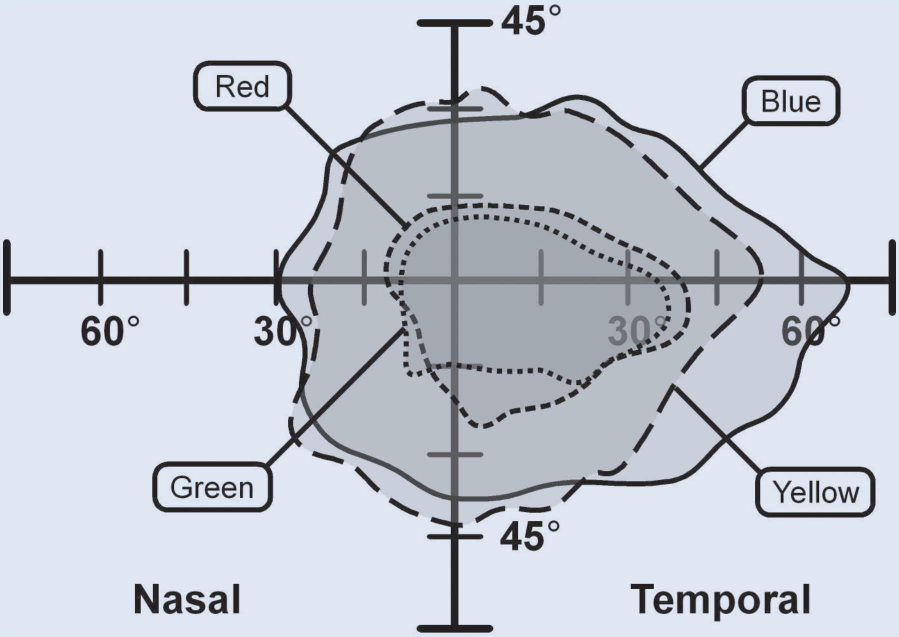
Expectation is another consideration. Since temperatures in the area rarely dropped below freezing and because no precipitation had fallen the previous night, the driver would not expect there to be any ice on the road. Such a perceptual set would markedly lower the likelihood of detecting the condition at any distance approaching that which might be expected had the driver been aware of the upcoming hazard.

Case Study 2: Crane Tipover

This case involved a 220-ft crane lifting 100,000-lb beams into place during construction of a bridge.

Figure 3

Monocular Color Fields



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Trucks delivered the beams to a position adjacent to the crane, which then picked up the beam after rotating to the two o'clock position relative to the front of the crane. After lifting the beam from the truck, the crane then rotated approximately 120º to the six o'clock position in order to place it into position on the new bridge. The first beam was placed on the bridge in a location farthest away from the crane relative to all beams to be placed that night; this first lift was well known to the operator to be the most demanding lift because it would place the crane closest to its operating capacity. On this night, the first lift was accomplished without difficulty. During the second lift, the crane tipped over, killing a nearby worker.

According to the construction plans devised based on the site geometry, trucks delivering the beams were to be positioned in very specific locations. Since all the beams were essentially the same weight, the critical factor encountered in placing the beams would be the horizontal distance the beam was away from the crane when positioned onto the bridge. Although it was clearly visible, the crane operator did not notice that the truck which delivered the second beam was incorrectly positioned when the lift was initiated. The crane was stable when the beam was initially lifted, but as it rotated and came to a position where the beam was directly abreast of itself (the three o'clock position—where the crane is most susceptible to tipping), the combination of the beam's weight and distance from the center of the crane caused the crane to tip over.

In this case, the operator, although highly experienced, was working under several negative circumstances. The accident occurred at approximately 3:00 a.m. (a point in the day/night cycle when human performance is almost at its nadir). It was extremely cold both inside and outside the crane cabin. The operator's attention was focused primarily on factors such as the guy lines and workers manipulating them as well as on the crane's slew rate during the turn. He was aware he was dealing with experienced truck drivers who would be expected to properly position their loads prior to his interaction with them. Having successfully completed the first and most demanding lift, he reduced his vigilance. He expected that the truck would be positioned correctly for the second lift and did not inspect that position at the time of the pick since he "knew" it would be fine.

In this case, the crane operator apparently was "blind" to the incorrect initial position of the load due to his focus on other details of the task. His attention was on maneuvering the load in a less-than-ideal lighting environment once it was secured to his equipment rather than on the more prosaic aspects of the task. The position of the truck was both open and obvious (since he was able to successfully complete the initial attachment of the load to the crane), and the instruments on his own control panel would have provided adequate information to ascertain that the crane would be in an unstable condition as the operator maneuvered the load. Unfortunately, he apparently became so focused on what he considered to be the critical details of the task that he essentially "missed the forest for the trees."

Case Study 3: Steamroller Incident

Routine maintenance was being performed on a steamroller by an experienced equipment operator before beginning work for the day. The maintenance required the operator to lubricate a portion of the machine that necessitated crawling partially underneath it. The steamroller was equipped with a parking brake and an attendant alerting light on the vehicle control panel that became illuminated once activated.

This was only the second time the operator had used the subject machine; the bulk of his experience was with similar machines on which the lever that operated the parking brake was engaged in a reverse manner to that on the current machine. The operator positioned the parking brake into what he assumed was the proper position (what would be the "engaged" position on machines he was familiar with, but which was the "disengaged" position on this machine), then started the machine so he could move it to gain better access to the portion of the machine that required lubrication. The diesel engine kept running, and as the engine and the transmission's hydraulic fluid began to warm up, the hydrostatic transmission eventually allowed the machine to begin moving, rolling over the operator's lower extremities and causing serious injury.

In this case, the operator's experience and expectation that all similar machines would operate the same way proved to be his undoing. While following the recommended procedures based on his experience and training, he failed to take into account that not all similar equipment employs identical controls or operating modes. The absence of a confirmation light on the instrument panel did not catch his attention after he positioned the parking brake lever into what he assumed was the appropriate position (in practice, attention is far easier to capture by the presence of a stimulus than by its absence). The status of the parking brake was clearly visible and easily determinable by looking at the instruments, but the operator failed to perform such a check. He expected that the parking brake would operate in the manner to which he was accustomed and "knew" that he had properly positioned the brake lever. The information necessary to prevent the subsequent accident was available to the operator, but he did not perceive it because his attention was not focused on it.

Case Study 4: Multicar Highway Crash

A middle-age male was driving a van on an interstate highway near a major Midwestern city. It was approximately 40 minutes after sunset. A semitrailer truck had preceded him down the same road approximately 15 minutes earlier, suffered a mechanical breakdown, and pulled off the highway and onto the left shoulder—or, more accurately, had been pulled *most* of the way off the highway; the rear end of the trailer was protruding approximately 1 ft into the leftmost lane of travel. The van driver contacted the rear of the trailer with his vehicle in passing, catapulting the vehicle into the adjacent lane and causing a multicar crash in the middle of the road. After the accident, the driver stated that he had not realized the trailer extended into the roadway, even though the four-way hazard flashers were activated on both the tractor and its trailer at the time of the accident.

Discussion with the accident victim revealed that the driver became aware of the presence of the stopped vehicle at an adequate distance to either bring the van to a stop or to effect a lane change prior to the collision. However, because of the low-light level at the time of the accident (little natural illumination and little additional illumination from the van's headlights), the driver based his assessment of the trailer's position on past experience—that is, a truck pulled off the road is a truck pulled *off* the road—–and focused his attention on switching lanes. Traffic close behind and overtaking him in the adjacent lane caused him to make more than a cursory glance into his side mirror to ensure that he had adequate clearance to change into that lane himself.

In such cases, the driver typically shifts attention between his forward path of travel and the effort to ensure adequate clearance into the adjacent lane. The glances forward primarily served to ensure that his own vehicle maintained its current position within its own lane and that no stopped obstacles were directly in his path of travel. Since he had (to his own satisfaction) determined the position of the stopped vehicle on the shoulder, only minimal attention would have been paid to verifying that assumption.

As the van approached the stopped vehicle, his headlights would have eventually provided adequate illumination to make it clear that the fog line of the highway was under the rear of the trailer, but likely this only occurred after the van had approached to a position where the driver's forward-directed attention was focused beyond the position of the trailer (that is, the driver was looking beyond the location of the trailer to allow himself time to react to any other potential hazards). Combined with the attention directed toward the adjacent traffic, he likely never noticed the actual position of the rear end of the trailer.

In this case, the driver's own experience and expectations with regard to the *likely* position of a vehicle pulled off the road effectively blinded him to its *actual* position. He formed a hypothesis about the trailer's position based on his experience and when sufficient information became available to disconfirm that hypothesis, his attention was focused on other aspects of the driving environment which he considered to be more critical at the time.

Case Study 5: Radio Wave Exposure

An independent painting company was contracted to paint a large radio transmission antenna on one of the world's tallest buildings. The antenna was used by multiple stations transmitting from it simultaneously. The contractor was scheduled to paint the antenna late at night (weather permitting) while many of the stations were off-line.

The host building and antenna owner hired a safety consultant to coordinate project safety. A system was set up under which the radio stations still in operation at the time of the painting were to switch to an alternate antenna at a prescribed time unless advised otherwise. This would protect the workers against exposure to high-intensity radio waves (radio transmission waves are not normally dangerous unless one is within 3 ft of the transmission point). Furthermore, the painters had radio wave intensity monitors to warn should the transmission system be activated inadvertently. The alarms on these monitors would, from time to time, activate due to transient radio waves and would have to be reset by each painter.

On the five nights before the accident, the antenna switchover had not been performed due to rain. On the night of the incident, the weather was questionable, but a decision was made to proceed. Before work started, each station was to call the safety consultant and confirm the switch to the alternate antenna. One station had not called, but the painters decided to ascend the antenna to begin the project anyway. During the ascent, the monitors sounded on a continuing basis. Annoyed, the painters put the monitors into their work buckets. Shortly after completing their ascent, one painter succumbed to radio wave radiation symptoms (e.g., headache, light-headedness, nausea). Prompt movement away from the vicinity of the active tower prevented what could have been a fatal fall.

Many people regard perception as a passive process in which the mind records the data that the senses gather. In reality, perception is an active process; it "creates" rather than "records" reality.

While this case does not involve visual perception, the principle remains the same. Information was available to the workers to tell them that the tower they were ascending was active, but the workers dismissed this information due to their perception that the activation of the alarms was a function of multiple false alarms, rather than a warning about a true condition (i.e., an active transmission tower). The workers basically filtered out information that may well have been critical to their survival.

This is similar to the phenomenon known as habituation, where repeated exposure to a stimulus reduces its latency to the individual. A common example is the construction worker who is so frequently exposed to backup alarms which do not affect him personally that he unconsciously begins to filter these alarms out of his conscious perception—at times to his own detriment.

Conclusion

Most engineers and scientists enjoy analyzing numbers and, thus, tend to gravitate to metrics that are easily quantifiable. Examples of this include measuring the amount of light falling on a surface, the brightness contrast between two objects or the optical size of a target. These types of measurements result in simple, straightforward analyses that aid in determining whether a particular object could be seen or not.

However, such measurements do not directly address the issue of whether that same object would likely be perceived by a particular individual, an issue which is much less straightforward. Perception is the process by which sensations are selected, organized and interpreted. What an individual perceives is shaped by and inextricably linked to his/her experiences, education, cultural values and the tasks in which s/he is currently engaged.

In reality, issues such as expectation, inattentional blindness, visual acuity and alarm validity must be taken into account when assessing whether a stimulus might have been perceived under real-world circumstances. The case studies presented offer examples of the difference between sensation and perception. Taken in context with the circumstances surrounding the incidents, one can often arrive at a potential explanation for what might otherwise be taken as inexplicable or even intentionally negligent behavior on the part of the victim in an accident. It can be difficult to avoid falling into this type of perceptual trap.

As noted, most individuals performing familiar tasks only process a fraction of the information available to them from their environment—those aspects that they deem important to the task at hand. Perhaps counterintuitively, it is often the experienced individual rather than the novice who is more prone to this type of error. This is not necessarily due to any type of complacency effect, but often rather to simple parsimony—they "know" from past experience where to focus their attention when all is proceeding normally. As a result, it is difficult to provide any type of engineering "fix" or training to counter this type of error. The information to avoid the problem is there, the individual simply does not take notice of and attend to it.

Perhaps the best approach SH&E professionals can take is to emphasize the potential for such errors during training. This will help to heighten the awareness level of such misperceptions. Risk perception on the part of an individual is a function of both the perceived likelihood of encountering a hazard and the potential consequences of not avoiding it. If the consequences of such errors cannot be reduced, the only solution is to raise the expectation of the likelihood of encountering them.

These issues do not suggest that errant perception on the part of a participant in an accident somehow absolves that individual of all responsibility for it, making the incident somehow the fault of the designer of the equipment or facility involved. While a reasonable understanding of how an individual might come to make a perceptual misjudgment is often possible, this does not necessarily excuse or justify the misperception itself. In each case study presented, had the individual involved been actively (rather than passively) attending to the task being performed, it is likely that s/he could have noted the critical information necessary in sufficient time to prevent the accident. The level of attention paid to open and obvious information in the environment is, in most cases, under the conscious control and judgment of the perceiver. ■

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