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Attention Failures Cause Workplace Accidents: Why Workers Ignore Hazards and What To Do About It

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Abstract

Accidents readily occur when workers are not attentive to the hazards of their work. For some professionals, such as workers in the construction and mining industry, exposure to workplace hazards occurs on a daily basis. Such repetitive exposure to workplace hazards poses unique challenges for the attention of workers. This review explores how, in the absence of negative consequences, repetitive exposure to hazards decreases attention to them. Recommendations, informed by the science of attention, suggest how to combat the tendency to ignore frequently-exposed hazards and restore worker vigilance, thereby reducing the frequency of workplace accidents. Experiential training incorporating virtual reality holds some promise.

Keywords

attention, workplace safety, threat habituation, virtual reality, learning

Tweet

Accidents increase when workers are inattentive to potential hazards. Repeated exposure to a particular hazard often results in a tendency to ignore it. Innovative worker training can rapidly restore attention to hazards.

Key Points

- With repeated exposure, workers tend to become less attentive to specific workplace hazards.
- The tendency to ignore a familiar hazard is a natural product of human attentional processes.
- Traditional approaches to safety training are ineffective at curbing inattention to hazards.
- Innovative approaches to experiential training incorporating virtual reality can rapidly restore vigilance to workplace hazards.
- Improvements to worker safety training, informed by the science of attention, are needed.

The Role of Attention in Information Processing

The world around us is rich, complex, and dynamic. Take, for example, a typical road construction work zone. Workers moving about such sites need to be mindful of their work task, the tool(s) they are using, the position and activity of other workers and the heavy vehicles they are operating, nearby vehicle and/or pedestrian traffic, and whatever obstacles might be positioned throughout the work zone (e.g., cones, framing). This is in addition to all of the task-irrelevant sources of information present in the environment that can be ignored, such as buildings beyond the worksite and surrounding nature. Processing all of this information all at once is simply impossible. From the standpoint of vision, what people can process is naturally limited by what is in front of their eyes: They are unable to see behind them. For better and for worse, however, human limitations in information processing go beyond limitations in the information available to our senses.

Like a computer, the perceptual system of the human brain has a limited capacity to process information. A person can only process a fraction of what is within their line of sight at any one moment in time. Fortunately, the brain has adapted to manage this limitation by processing information selectively (Desimone & Duncan, 1995). In perception research, *attention* refers to how the brain determines what perceptual information is processed. When a person directs their attention to something, that is what they will "see" in their mind's eye. The limited-capacity processors in the

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brain will process the attended information in some detail, while unattended information will be processed on a very shallow level, often not even reaching awareness (Mack & Rock, 1998). The challenge, then, is for attention to select the information that is important to the survival of the person and to the success of their current endeavor.

Many people have the intuition that they see everything in front of them, but our intuitions are not always correct. The scientific evidence for the idea that people often fail to process what they do not pay attention to, even if it is right in front of them, is overwhelming. Simply responding to the appearance of an object will be delayed until the observer can shift their attention to that object (Failing & Theeuwes, 2014; Folk et al., 1992; Posner, 1980), which requires neural computations within the system for controlling attention in the brain (Corbetta & Shulman, 2002; Yantis et al., 2002). When two objects compete for attention, the attended object is more strongly reflected in the neural code by which a person represents their world (Desimone & Duncan, 1995; Kamitani & Tong, 2005). Perhaps most saliently, people frequently fail to even see and report something they do not direct their attention to (Mack & Rock, 1998; Rensink et al., 1997), resulting in a phenomenon termed *inattentional blindness*. The illusion that we see everything in front of us is driven by the fact that we have some awareness of the richness of our environment, informed by memory for what we might have recently paid attention to, and we pair this awareness with ignorance concerning unattended information to create a false sense of the whole of our environment.

The Importance of Attention in Workplace Safety

The prior section lends understanding to the reality that we are often unaware of what we do not pay attention to until something bad happens or nearly happens as a result of our inattention. For example, when driving, we do not realize that we failed to recognize a pedestrian crossing the street until we either collide with them or they manage to capture our attention moments before a potential collision, or at least at a moment well after we know we "should" have seen them coming. The fact that we did not see the pedestrian earlier, when they logically must have been in plain sight given where they were when we first noticed them, tells us that we must have overlooked them. Likewise, we might leave the stove on despite looking right at it before leaving the kitchen, only to realize our oversight when we next use the stove or possibly when we notice that our house has caught fire. You only know what you miss when you notice something too late and/or there are felt consequences for your ignoring.

In the workplace, accidents can happen when a person ignores a hazard. Struck-by accidents can happen when a worker fails to respond to an oncoming vehicle (Daalmans, 2012; Duchon & Laage, 1986; Pegula, 2013), in extreme cases approaching at under 5 miles per hour (American Road and Transportation Builders Association, 2013; The National Institute for Occupational Safety and Health, 2020). Electrical workers can be shocked when they begin to ignore the state of the circuits they are working with and their proximity to these circuits (Castillo-Rosa et al., 2017), and builders can fall from high places when they ignore potential trip hazards or their proximity to an open ledge (Hasanzadeh et al., 2018). In many cases, these accidents can be classified as "looked but failed to see" and "listened by failed to hear" in that the hazard was in plain sight or earshot, but the individual simply did not process the hazard until it was too late (e.g., Herslund & Jørgensen, 2003).

Even with all of the safety advances provided by modern technology, workplace accidents remain all too common. Every year, numerous fatalities and injuries result from accidents in workplaces: in 2021 alone, 5,190 fatal work injuries and 2.6 million nonfatal work injuries were reported in the United States (U.S. Bureau of Labor Statistics, 2022). Despite periodic safety training, the majority of accidents in occupational workplaces occur due to workers' unsafe behaviors (Choudhry & Fang, 2008; Xia et al., 2017). After daily exposure to specific workplace hazards, workers become familiar with working in close proximity to these hazards (Ye et al., 2020). Consequently, workers become less attentive to the hazards and engage in unsafe behaviors resulting in fatalities and injuries (Arezes & Miguel, 2008).

The Role of Learning in Directing Attention

From what has been discussed so far, it may be tempting to conclude that the solution to the problem posed by inattention in the workplace is to motivate workers to be more attentive to the hazards in their environment. Simply put, these problems seem like they would not be problems if workers merely tried harder to focus on the most safety-critical information in their workplace. Not unrelated to the illusion that we "see" everything in front of us, however, this intuition similarly belies the nature of how the human attention system works.

Most of how we direct our attention is automatic and nonconscious (Anderson, 2018). For the most part, we do not actively think about what we should direct our attention to. We typically think about the behaviors we want to engage in—which include work tasks—and attention follows from that. And this happens for good reason: it would be quite burdensome for us to have to constantly devote mental resources to considering how we should direct our attention, and the allocation of attention would often be slow and inefficient if it were constantly dependent upon conscious direction (Anderson, 2021; Theeuwes, 2018). Indeed, directing our attention in an intentional way is a mentally effortful process (Anderson & Lee, 2023).

In many cases, we automatically direct our attention in ways that are strongly influenced by what we have learned about our environment through prior experience. When we consistently search for a particular object because it is pertinent to our task, we will come to habitually attend to this object when we encounter it in the future, even when we know such attention is situationally unhelpful (Anderson et al., 2017, 2021; Anderson & Britton, 2019; Kim & Anderson, 2019a, 2019b). For example, we may take on a new role at work, but find ourselves directing attention to the things that used to matter for our former work role for quite some time. Things that we associate with reward tend to automatically draw our attention, even when we actually try to ignore them (Anderson et al., 2011; Anderson & Kim, 2019a, 2019b; Kim, Gregoire, et al., 2021; Kim, Lee, et al., 2021), for example a tasty dessert that draws our attention even though we are resolved to diet. Things that we associate with aversive outcomes also tend to automatically draw our attention (Anderson & Britton, 2020; Kim & Anderson, 2021; Schmidt et al., 2015), which is believed to support the identification of and responding to threat (Mulckhuyse, 2018; Öhman & Mineka, 2001; Vuilleumier, 2005). A variety of other learning-dependent influences shape how we direct our attention, in many cases reflecting the statistics of the environments we find ourselves in and our attention system's attempt to optimize our ability to selectively process what is relevant to our ability to accomplish our task goals while ignoring what is not (see Anderson et al., 2021, for a review).

In these ways, much of how we direct our attention can be thought of as a learned response. Although capable of misguiding attention, automatic learning-dependent attentional processes are theorized to be overall beneficial and adaptive (Anderson, 2021). That is, these processes in many cases improve the efficiency of information processing at the occasional cost of selectively processing something that is situationally irrelevant and/or failing to select something important. However, there are situations in which automatic attentional processes can result in systematically maladaptive patterns of information processing, and as will be argued in the following section, hazardous work environments constitute one such situation.

Threat Habituation as Learned Ignoring

Not only is what we tend to focus our attention on in many cases influenced by automatic attentional processes, but so is what we tend to ignore. The human attention system is built to optimize information processing, and one of the ways it accomplishes this is by suppressing the processing of things that have consistently proven distracting or uninformative. In the laboratory, bright and colorful objects or loud noises that have no bearing on the task at hand will tend to draw attention and distract from task performance (Anderson, 2016; Itti & Koch, 2001; Theeuwes, 1992, 2010). However, when such distractions occur in predictable ways, people can become much better at ignoring them (Britton & Anderson, 2020; Kim & Anderson, 2022; Kim, Ogden, et al., 2023; Stilwell et al., 2019; Wang & Theeuwes, 2018). In fact, under some circumstances, people can ignore predictable distractions entirely, such that they become easier to ignore than things that are normally less distracting (Gaspelin et al., 2015; Gaspelin & Luck, 2018b).

One of the ways in which perceptual systems adapt to frequent but irrelevant information is *habituation*, a phenomenon by which the same perceptual experience will come to generate a weaker response in the brain with increasing exposure (e.g., Schmid et al., 2014; Wilson & Linster, 2008). Habituation can explain how people become progressively better at ignoring salient information that is normally attention-grabbing (Turatto, 2023; Valsecchi & Turatto, 2023) and is believed to affect the processing of workplace hazards that a person is frequently exposed to (Lee & Kim, 2022; Ortiz et al., 2000; Weyman & Clarke, 2003). In the workplace, threat habituation manifests as a progressive reduction in vigilance towards a potential hazard. Signals for potentially hazardous information in the environment, for example a backup warning alarm, initially evoke regular checking behavior, but such orienting rapidly declines with consistent exposure in the absence of negative outcomes, until the potential threats go completely unchecked. Threat habituation provides a model for patterns of behavior observed in actual workplace settings (Lee & Kim, 2022; Weyman & Clarke, 2003) and can be rigorously measured when individuals perform work tasks in an experimentally controlled virtual environment (Kim, Anderson, et al., 2021; Kim, Gregoire, et al., 2023; Kim, Yan, et al., 2023).

Recent evidence from the laboratory confirms a blunted response to a frequently exposed warning alarm in the auditory system of the brain in construction workers, consistent with habituation at a sensory level (Kim, Gregoire, et al., 2023). It is literally as if a frequently exposed hazard is in this case quieter than it actually is, which is likely also true with respect to visually-evoked activity in the brain (see Adam & Serences, 2021; Gaspelin & Luck, 2018a; Won et al., 2020). Given such blunted responding in the brain, it should come as little surprise that frequently exposed hazards would become increasingly ignored.

Threat habituation marks an unusual case in which a normally adaptive brain response is situationally maladaptive. As outlined at the outset of this paper, people are frequently exposed to far more information than they can process at any one moment. Many of the things people are frequently exposed to are predictably irrelevant and of no consequence for what they are trying to accomplish, and so it makes sense to ignore such uninformative aspects of an environment. In the case of workplace hazards, a worker may be exposed to the same potential hazard literally more than a thousand

times over the course of their career. With each passing exposure, experience tells the worker that these potential hazards or the warning alarms that herald them are inconsequential. Whenever the worker directs their attention to such potential threats, all such attending ever accomplishes in their experience is to break their focus from the task at hand and slow down task completion. Workers are essentially learning that the potential threat to which they are frequently exposed is in fact a safe stimulus that is beneficial to ignore. The trouble is simply that accidents constitute highly infrequent events that are not effectively learned about from real-world experience by virtue of how infrequent they are, which belies the underlying reality that the threat is genuine and the consequences of ignoring signals that warn of this threat can be devastating.

Traditional Approaches to Safety Training and Why They are Ineffective

The aforementioned scientific findings concerning human attention lend insight into why traditional approaches to safety training have been limited in their effectiveness. These approaches include the use of instructional materials in a group setting, typically emphasizing the importance of workplace safety and lecturing on the potential consequences of unsafe behavior, and "toolbox talks" before the launch of a project that serve as a reminder of safety importance (Namian et al., 2016). Although these approaches to safety training may produce some measure of fact-based learning and improve knowledge of safety practices, they do not address how the human attention system works and how it can be most effectively influenced.

How we direct our attention is, for the most part, not the product of a conscious and intentional process. Any effect that learning new safety knowledge or being provided with safety-related reminders has on how a person directs their attention will quickly subside, basically as soon as the person stops deliberately thinking about the information from the safety lesson, at which point more automatic modes of information processing that serve as the default for a person will take over. It is indeed unrealistic to expect anything beyond this, as constantly rehearsing safety-related information that would be necessary to sustain intentional, goal-directed attention to potential workplace hazards would consume a person's memory resources, detracting from their ability to make meaningful progress with their work task (see Anderson, 2021). Attention and other mental resources are needed to perform even simple tasks, and because attention is a limited resource, one cannot simultaneously direct their attention to all of the various potential hazards in their work environment and to the content of their work task simultaneously.

Although sustaining attention to potential workplace hazards is not feasible, neither would it be feasible to expect workers to rapidly switch attention between the performance of a work task and scanning the work environment for a potential hazard in an intentional manner. Rapidly shifting attention between the performance of work and scanning for potential hazards would be extremely mentally demanding, significantly detracting from actual work performance. Workplaces are also dynamic environments and potential hazards are diverse and can be introduced at unpredictable points throughout a workday. There would be a high risk of hazards coming into the proximity of the worker between checks, and what exactly the worker would be checking for would be either changing in a manner not easily tracked (as different hazards move in and out of their proximity) or simply unwieldy (where the worker tries to monitor for every possible hazard simultaneously). Furthermore, it is questionable whether people could even meaningfully engage in sustained periodic scanning of their environment for even a single potential hazard, as sustained attention is subject to mental lapses under normal conditions (Esterman et al., 2013; Esterman & Rothlein, 2019; Fortenbaugh et al., 2017), which is one of the limitations that more automatic modes of directing attention is believed to help manage (Anderson, 2021). For all of these reasons, safety training focused on increasing safety knowledge or providing reminders concerning the importance of safety-related practices does little to curb the experience of threat habituation and the consequences it has on worker attention and safety.

Curbing Attention to Hazards Through Experiential Learning

A novel approach to addressing threat habituation in the workplace is to leverage what is known about learning-dependent attention to strategically curb the attention of workers. As described earlier, attention is automatically biased toward things associated with negative or aversive outcomes, which is thought to play a role in facilitating threat detection (Anderson & Britton, 2020; Kim & Anderson, 2021; Schmidt et al., 2015). The key here is that the negative or aversive outcome needs to be personally experienced in order for it to influence attentional learning, which is why simply informing workers about the threat that hazards pose does not influence attention in this way. Anecdotal observations from actual work environments suggest that experiencing an accident or near-accident can result in sustained improvements in vigilance toward signals for the potential threat in question (Bohm & Harris, 2010; Burke et al., 2007; Daalmans, 2012; Duchon & Laage, 1986). One possibility, which was recently tested in a controlled virtual work environment, is that such anecdotal observations reflect learning-dependent shifts in how people direct their attention, driven by a single, highly salient aversive emotional experience (Kim, Gregoire, et al., 2023).

Although it would not be ethical or beneficial to expose workers to actual near-accidents, with advances in virtual reality (VR), it is possible to evoke a realistic accident experience in a safe environment. We had both construction trainees and experienced construction workers perform a virtual road debris clearing task in which we measured their work performance. They were provided traditional safety-related instruction and encouraged to exhibit safety practices during performance of the task. Unbeknownst to our participants, if they repeatedly ignored (failed to orient to) a backup warning alarm of a street sweeper that would periodically approach them, the sweeper would then approach them on a collision course and, if they were not vigilant to get out of the way, would run over their virtual self and trigger an accident scene.

In spite of the immediate safety reminders, virtual accidents were observed in the majority of participants, with orienting to the warning alarm progressively decreasing in frequency and sensitivity throughout the performance of the virtual work task (Kim, Anderson, et al., 2021; Kim, Gregoire, et al., 2023; Kim, Yan, et al., 2023). This was particularly the case for participants prone to boredom (Kim, Yan, et al., 2023). Such observation provides an experimentally controlled demonstration of threat habituation. Experiencing the virtual accident increased the ability of the warning alarm to evoke checking behavior, which was sustained for at least one week post-accident (Kim, Anderson, et al., 2021; Kim, Gregoire, et al., 2023; Kim, Yan, et al., 2023). Habituation to the warning alarm was undone by the virtual accident; the blunted neural response to the warning alarm in experienced construction workers—evident prior to experiencing the virtual accident—was no longer evident a week following the virtual accident (Kim, Gregoire, et al., 2023). Ongoing work from our labs suggests that restoring attention to potential hazards evoked by the experience of a virtual accident may translate to how workers direct their attention in their actual work environment.

From this evidence, experiential learning concerning the consequences of inattention and the threatening nature of certain objects, when occurring in a safe virtual environment, can effectively curb attention in ways that traditional instruction-based learning falls short of influencing. Current research has focused on aversive conditioning via a virtual accident experience, but approaches to virtual training could be adapted to leverage other learning-dependent influences on attention as well. For example, workers could practice orienting to specific potential hazards when they come within a certain proximity, to the point that such orienting becomes a habitual attentional response. Such training could be coupled with adaptive attentional feedback (see Anderson & Mrkonja, 2021, 2022) to ensure the engagement of attentive behaviors that could become habitual with practice. Such training could even be paired with a system of reward contingencies for vigilance toward potential hazards; this might accentuate training benefits (see Anderson et al., 2011).

Policy Insights

Recent research provides converging evidence for the severity of threat habituation in spite of current approaches to promoting worker safety, and the value of experiential learning in curbing such habituation. Companies who expose their workers to potentially hazardous conditions and government agencies tasked with monitoring and/or facilitating safety practices would be well advised to explore alternative and augmented approaches to promoting worker safety informed by this research. Here we offer several specific policy recommendations, spanning action items that can be implemented in the short-term and suggestions for targets of investment for further development to facilitate broader future impact.

Specific Policy Recommendations

1. Although worker training aimed at imparting safety knowledge is important, such training should be supplemented with experiential learning designed to curb the attention of workers, as only experiential learning is likely to have a meaningful impact on threat habituation. The ability of VR to expose workers to "teachable moments" that are evocative yet safe makes training in a VR setting attractive in this context.
2. Classroom-based training should cover the attentional limitations that workers face. Although such coverage is unlikely to itself remedy automatic influences on attention that contribute to threat habituation, it may help motivate workers to be a little more vigilant with respect to how they intentionally assess their environment for potential hazards if they know what they are prone to do. The utility of such instruction is a good avenue for future research, as it reflects a potentially cost-efficient way to help mitigate the consequences of threat habituation.
3. The reality of threat habituation should be taken into account when assessing safety culture and practices. An accident attributable to threat habituation is not necessarily indicative of poor safety culture; it may simply reflect limitations in human attention that are challenging to manage. Likewise, the frequency of accidents that could be attributable to threat habituation is unlikely to provide a good metric by which to examine the impact of interventions targeting safety culture, as a positive impact on safety culture may have limited to no impact on threat habituation itself. Individuals involved in program evaluation would be well-advised to account for the realities of threat habituation in their assessments.

4. At present, the cost of VR-based training remains expensive and in many cases cost-prohibitive for large-scale work operations. It also requires significant time and space resources if training is to happen at worksites. For the full range of benefits of experiential learning to be realized in the effort to combat threat habituation, investments in the cost-efficiency of VR by technology developers could have significant impact. Alternative approaches to experiential learning using more cost-efficient technology, such as that found on personal smartphones, could also be explored and developed.
5. For large-scale work operations, while VR-based training remains costly to implement, efforts might be taken by companies to identify which of their workers are at greatest risk of threat habituation. Identifying such workers could help maximize the benefits of a limited resource like VR-based training. Identification of at-risk individuals could incorporate personality assessments (see Kim, Yan, et al., 2023), the development and implementation of perceptual tests probing sensitivity to safety-related information, and potentially the automated analysis of video footage that captures the frequency of looking toward potential hazards in the actual work environment (e.g., recorded from a camera mounted on a construction helmet).
6. In the workplace, warning alarms tend to be of a fixed and monotonous nature, for example the constant beeping of a backup alarm that never changes day-to-day. This is exactly the kind of stimulus that most strongly promotes threat habituation. It would be advisable for companies and funding agencies that support basic research to invest in the development of more dynamic alarm systems that are less prone to evoking habituation in workers. As electroencephalographic devices and other devices capable of recording brain activity become increasingly cost-efficient and less burdensome to wear, it may become feasible for alarms to adapt based on neural indicators of threat habituation at the sensory level (see Kim, Gregoire, et al., 2023). For example, the sound evoked by an alarm could change when it is recognized by an audio recorder while evoking a blunted response in the brain of a nearby worker.
7. Although the continued development of automated safety features in heavy construction and other work-related equipment is likely to have a broad range of benefits for worker safety, such developments will never themselves remedy the realities of threat habituation (Chan et al., 2020; Choi et al., 2019; Ferreira-Diaz et al., 2009; Wang et al., 2017). As no safety feature will ever be fool-proof and any safety feature assumes equipment is used in anticipated ways, the need to manage the risks posed by threat habituation is ever-present. Safety features should not be viewed as a solution to the risks that workers pose to themselves with respect to threat habituation.

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