Inattentional Blindness: Present Knowledge, Recent Research and Implications for the Nuclear Industry.

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Abstract

Inattentional blindness can occur when our attention has been assigned to a primary task and not enough attentional resources are left to detect what can be a very important unexpected event. This unexpected event is often something that would be detected under normal conditions. Recent research has shown that perceptual load, and qualities of the unexpected stimulus can impact the occurrence of inattentional blindness. As the nuclear industry has situations of high perceptual load, consideration should be given to the implications of this research.

1. Introduction

Inattentional blindness, sometimes also referred to as attentional blindness is the curious phenomenon of not visually perceiving something in your visual field that most people would view as being obvious. A memorable real world example is the year 2000 incident where an American submarine hit a Japanese fishing vessel even after the Commander did a visual sweep of the surrounding water through the periscope. The Commander had been informed that there were no sonar contacts and at the time of his periscope sweep there were several high profile visitors in the control room. There are numerous examples of drivers of cars and motorcycles pulling out in front of oncoming traffic, bicycles or pedestrians causing damage, injury or death. While none of these events may have obvious ramifications for the nuclear industry, this paper is meant to highlight present knowledge of, and recent research into inattentional blindness that may have implications for work done in our facilities. A brief primer into how we see things is given in the following sections followed by a deeper look into inattentional blindness.

2. The biology of sight

Figure 1 below shows a fairly remedial diagram of the human eye and is courtesy of the National Eye Institute. Light rays entering the eye are focussed on the retina by the cornea and the lens. The retina itself contains millions of Rods and Cones which transduce light into electrical signals that get sent from the eye to our brains visual processing centers.

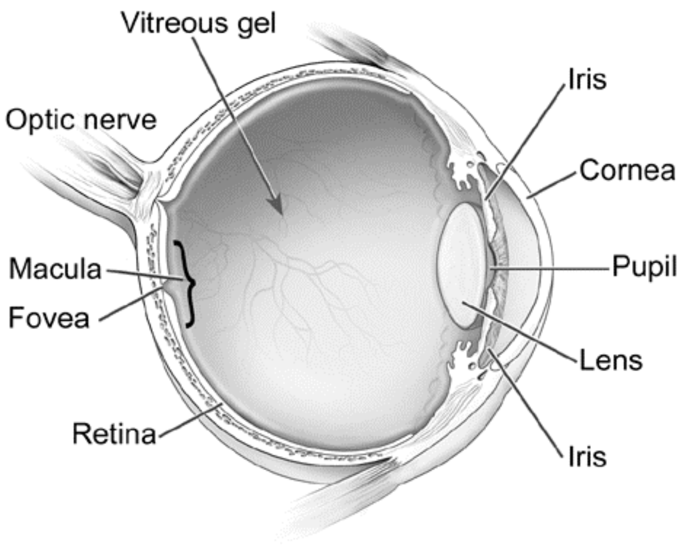

Figure 1: Diagram of the Human Eye

Rods are only black and white detectors and don't need much light to be activated, but because of the way the signals from them are collected, offer a fairly low resolution or grainy image. Rods are what we use to see in near dark situations. Cones on the other hand offer us much higher resolution scenes that are in colour, but unfortunately require more light to activate. Cones are what give us most of our visual information in well lit situations.

A part of our retina called the Fovea is the only place on our retina that contains ONLY cones. This small portion of the retina, which is about a millimetre in diameter and accounts for about 0.01% of the retina's surface area, is what we try to focus visual images on when we are paying close visual attention to them. The interesting part of course is that the fovea, representing only about 0.01% of the surface area of the retina feeds approximately 10% of the retinopic map in the visual cortex[1].

The cone of light coming into our eye that lands on our fovea, (that represents 0.01% of our retina's surface area), is roughly equivalent to what would come from a disc about 7-10 cm in diameter about 2 meters in front of us.

3. The psychology of seeing

While the biological underpinning of our sight is important to understand how we see things, the real magic occurs in the brain as these images are processed. While we may feel that what our eyes are receiving is flawlessly translated in pristine perfection to our consciousness, the reality is somewhat different. When we view a visual scene in front of us we point our fovea at various portions of the picture in what are called "saccades" which are 20-200 ms movements from one point to the next. We then stop for a brief period of time, typically about 250 ms, in what are called "fixations" and then our eye saccades off to the next fixation point. Our brains then stitch together the images from the multiple fixations into what is presented to our consciousness as a seamless, coherent "picture" [1].

It is important to remember that each of these fixations only grabs a snapshot of good detail from a small portion of our visual field, before we saccade off to the next fixation to grab another snapshot of a small portion of the visual field. If, for example an Authorized Nuclear Operator (ANO) is standing 6 feet away from the control panels, the fixations each grab only about a 7-10 cm diameter circle of good, detailed information at a time.

Studies with eye tracking machines have shown us that we actually only point our fovea at small, select parts of any given visual scene and our brains smooth out, or fill in what detail wasn't directly noted with what is expected so that the visual scene doesn't appear to have gaps in certain spots[1].

One of the underlying questions in all this of course is what determines where we point our foveal vision. The answer to this is that generally, our attention guides where we point our fovea. Our attention can be drawn towards something by certain qualities that we are programmed to pay attention to, like movement and flashing lights. Our attention can also be unconsciously directed by what our experience has taught us to look at. This happens when we drive cars and are scanning the road in front of us or when we look at someone's face to help ourselves interpret unspoken signs and signals. Finally we pay attention to things we are consciously driving our attention towards like when an ANO deliberately moves from one display to the next to check the status of some parameter they are interested in[1][9].

4. What is inattentional blindness

The earliest research into inattentional blindness occurred in the 1990's and researchers have developed a series of ways to test for it. In a number of studies the subjects are asked to distinguish which arm of a cross is longer throughout a number of trials and every now and then an object is presented at the same time as the cross at some location in the subject's visual field and they are asked to identify this shape, or some quality of it, that they had not been warned about[2]. When subjects fall victim to inattentional blindness in these experiments they report that they saw no other "unexpected" object. Other studies like this use letters of different colours as both the primary task and the unexpected stimulus[3]. In one of the most famous examples of inattentional blindness research, the researchers had subjects view a scene where 3 students in white t-shirts and 3 students in black t-shirts were passing basketballs while weaving around each other. The subjects in this experiment were asked to count the number of passes made by the team in the white t-shirts. The whole clip is about 75 seconds long, but at about the 45 second mark a student wearing a Gorilla suit walked into frame proceeded to the middle of the screen, beat its chest a few times then walked off. To most viewers this would seem a fairly obvious, and rather odd, event; but the results showed that almost half the subjects didn't see the gorilla[4]. While the research delves into various factors surrounding inattentional blindness, the fundamental issue is that the subjects are regularly unable to report the presentation of what is objectively a fairly obvious stimulus.

Inattentional blindness then is when we are not consciously aware of an unexpected, yet otherwise noteworthy object, in our visual field. We essentially become "blind" to that object because we did not pay attention to it.

5. What the research is saying about inattentional blindness?

In that landmark study by Simons & Chabris (the one with the Gorilla)[4], they also had trials with a woman carrying an umbrella walking through the frame for a few seconds, again clearly visible. Of interest is that the subjects consistently noticed the woman carrying the umbrella more frequently than they noticed the gorilla. The authors in this study concluded from their series of experiments that there is no perception of objects without attention. They also suggest that inattentional blindness will occur more when the primary task the subjects are engaged in becomes more difficult and that the unexpected event may be more easily detected when it is more visually similar to the items in the primary task.

In a 2007 study, Cartwright-Finch & Lavie[2] ran four separate experiments to tease out the effects of perceptual load on the likelihood of the subject experiencing inattentional blindness. Their study used trials where the subject had to determine the colour of cross arms in a cross displayed on screen, other trials where subjects had to state which arm of the cross was longer and additional trials which required the subjects to perform a visual search in where they had to distinguish between an X and an N amongst some visual clutter. In all cases there was the occasional unexpected stimulus of a black square presented within the visual field. The authors in this paper took great trouble to carefully manipulate the amount of perceptual load in their trials (more or less clutter in the visual search, or easier/harder line length discriminations) and came to the conclusion that the amount of perceptual load had a direct impact on the likelihood of cases of inattentional blindness. The more perceptually challenging the primary task is, the more likely the subject is to miss an unexpected stimulus.

In a study with multiple individual experiments, Most et al[5] used a variety of experimental conditions to tease out some of the impacts of the visual qualities of the objects in the primary task and in the unexpected stimulus and how these qualities might impact inattentional blindness rates. What the authors found was that the unexpected stimulus would be more likely to be noticed if it was more visually similar, in some key parameter (shape or colour) to the objects in the primary task than if the unexpected stimulus was more unique. The researches put forward the possibility that we define characteristics for the set of information we are trying to extract from our visual field and these characteristics become a sort of filter for us to include or exclude objects from conscious consideration. The authors put forward the theory that the probability of someone noticing an unexpected stimulus is directly related to what they have set their minds to see.

In a series of related experiments Beanland & Pammer[3] used a computer based display where the primary task was for the participants to count how many “bounces” off the sides of the display were made by certain letters that were white. The unexpected stimulus was a dark grey coloured different letter or unique symbol. The interesting part in this experiment was that the authors used eye tracking equipment to see how close the subject’s fixations got to the actual unexpected stimulus. The results of their experiments showed that while there is a slight tendency for people who notice the unexpected stimulus to spend a little more time fixated within 2 degrees of the object than people who don’t notice it, they noted that people can fixate directly on top of the unexpected stimulus and still not notice it. Conversely, during their research they also found that some of the subjects that noticed the unexpected stimulus did not fixate on, or even particularly close to, the unexpected object that was noticed. Their experiments confirmed previous findings that the difficulty of the primary task has a direct impact on the likelihood the subject will notice the unexpected stimulus. The harder the primary task, the more likely they will suffer from inattentional blindness and miss the unexpected stimulus.

In another interesting experiment[6], the authors used a computer based trial similar to that used in several other experiments where white and black letters “bounced” off the walls and the subjects had to count the bounces. In their experiments the unexpected stimulus was a grey cross and there were also conditions with audio tasks added to increase the difficulty. While this experiment certainly showed many instances of inattentional blindness as participants missed the unexpected stimulus, the fascinating part was the effect the unexpected stimulus had on the accuracy of counting the bounces (the primary task). What the authors found was that the accuracy of the primary task (counting bounces) was better when the subjects **noticed** the unexpected stimulus than if they didn’t notice it. There was a performance cost if the subject failed to bring the unexpected stimulus to conscious awareness. Just to be sure they hadn’t messed something up, the authors ran variants of the experiments a few more times and found that the performance on the primary task was the same for people that noticed and didn’t notice the unexpected stimulus on the trials when no unexpected stimulus was present but as soon as the unexpected stimulus entered the screen, primary task performance dropped only for the people who **did not** see the unexpected stimulus.

While the previous studies almost exclusively focussed on inattentional blindness when engaging in a primary task that was visually based Hyman et al[7] looked at several conditions in an observational study as subjects navigated their way across a large open square on the campus of an American university. The relevant part of their study had a unicycling clown riding next to the common pathways and had experimenters question people who had just walked across the square. The trained observers classified walkers as single, walking with one other person, walking while listening to an electronic device and walking while talking on the cell phone. As well as asking the subjects about noticing the unexpected stimulus, the observers also recorded how many direction changes were observed, walking speed and how many times they swerved to avoid obstacles. The authors in this study concluded that talking on the cell phone increased the likelihood of inattentional blindness based on the results that subjects talking on the cell phone missed the clown more (by a statistically significant margin) than all other walkers. They also weaved more and walked slower (though the subjects walking in pairs also walked more slowly as well). This study, while not being conclusive in and of itself clearly points towards the possibility that inattentional blindness may increase not only with higher visual demands, but possibly also with higher central processing demands.

6. General discussion

The theoretical framework which seems to most successfully integrate these results is the perceptual load theory proposed by Lavie[8]. In this theory, Lavie proposes that the early selection of which information gets processed is limited by attentional resources. When the perceptual processing capacity exceeds what is being demanded by the primary task then irrelevant stimuli will “capture” the remaining processing capacity, allowing the individual to notice the unexpected stimulus in the inattentional blindness trials. However, when the primary task at hand consumes the available processing resources, there is no more to perceptual capacity to capture and the unexpected stimulus and it goes unnoticed.

In a sense then, Lavie proposed that perception is a limited process, but that to the extent that there are uncommitted resources available, it is an automatic process. Another way to look at this is that perceptual processing is guided in a top-down manner until the necessary resources are allocated to the high priority task. The allocation of any leftover resources is then allocated in a bottom up manner, driven by the characteristics of the unexpected stimulus and the available perceptual resources.

Nearly all of the research noted in this paper showed that an increase in perceptual demands on the primary task led to an increase in the incidence of inattentional blindness. Consistently it was also shown in several experiments that the unexpected stimulus was always or almost always noticed in the very low demand trials. The research into the impact of the visual similarities between the unexpected stimulus and the primary task objects seems to imply that when our attention is “casting its net” to catch the necessary information to process for the higher priority or “primary” task, the unexpected stimulus is more likely to get caught in the net because of its visual properties and it is more likely to be consciously noticed.

Finally, the last study discussed in this paper[7] implies that the attentional resources directed at the perceptual load may also be limited by the attention directed at non-visual sources (talking on the cell phone). This view is consistent with the implications of the model of human processing put forward by Wickens and Hollands[9] in that when dividing the limited resources a subject may emphasize attention on one task (talking on the cell phone) reducing the resources made available to other tasks (noting the unicycling clown, or navigating around obstacles).

7. Implications for the nuclear industry

There are many cases when inattentional blindness can impact on an individual’s life. Whether it is missing that there is a pot boiling on the stove because we are engrossed in the crime show on TV, or missing the presence of a dog at the side of the road while driving down the highway because we are trying to tune the car radio, there are many cases in a humans experience where the perceptual demands of the task we are undertaking helps us miss some unexpected, yet possibly important event that needs to be noticed consciously.

In a Nuclear Power Plant, it is fair to say there are times when perceptual processing demands can be fairly high on employees. Planned conditions such as coming down for an outage or coming up from one can still impose a significant demand on the ANO’s resources and unplanned conditions such as the loss of grid event several years back can cross the line into extremely demanding. The theoretical frame work of perceptual loading as well as the results of the individual research projects discussed in this paper offer some guidance in how the possibilities of an inattentional blindness incident can be reduced.

One of the first steps that would be helpful to guard against inattentional blindness is to provide education about the phenomenon to the employees that are trying to defend against it. One of the points made in the Hymen et al study[7] was that research into drivers and cell phones showed that the drivers greatly over estimated their driving performance when talking on the cell. Most drivers reported no degradation at all even though in many cases they showed objective driving errors at a level similar to those made by drivers who were legally drunk. Helping employees understand the factors that lead to inattentional blindness will help them recognize situations where they might be more at risk. It may also help smooth the way for procedural or policy shifts meant to decrease the likelihood of such inattentional blindness events.

Reducing known irrelevant distraction sources during attention demanding tasks would be a useful practice. Recall that according to perceptual loading theory unexpected events are more likely to be captured when there are spare attentional resources left over after the necessary resources are tasked to perform the primary task. If a significant, yet unexpected stimulus must compete with a host of other attention seeking, yet irrelevant, stimuli then the unexpected event we would hope to catch will be less likely to get caught. In a practical sense this could mean identifying resource intensive tasks in the work plan for the day and restricting access to the employees performing the task for the duration of its’ performance. This strategy could, for example, be used in the control room during shift turnover, during transients or during certain tasks like approach to critical or certain SSTs. In the field this could mean creating safe work areas restricting access to other employees not just for their safety, but to reduce distractions for the employees performing the work.

Adding a non-committed set of eyes (or maybe more accurately "adding a pool of uncommitted attention") to highly attention intensive activities would also be of benefit according to perceptual load theory. By suggesting this, I am proposing that there will be activities, planned and unplanned that require such a degree of attentional resources from the employee that there is benefit in having a like qualified employee standing back and observing. This less involved employee essentially is there to make sure the employee engaged in the primary task does not miss some important piece of information because they are attentionally "buried" by the task at hand. The employee standing back in this type of situation would need to be properly trained to understand they are not there so much to review the actions of the primary employee (and possibly becoming as attentionally consumed by the ongoing actions as the employee performing them) but to act as an attentional "crutch" to help ensure the "gorillas" don't get missed.

From a design perspective, there are some possible design cues that can be teased out of the present literature, or at the very least areas that have been highlighted for future study. Certainly, the ability to pause, silence or temporarily stop less important alarms during events that activate a large number of them would be beneficial as the ANO in such conditions will be experiencing a very high perceptual load thereby making them more likely to fall victim to inattentional blindness. Panel design may also be influenced with respect to the appearance and placement of displays in the sense that displays that will need to be compared for the same tasks may benefit from being an identical or at least similar design. Conversely, if two unrelated displays are located close to one another, one may act as a distracter to the other. Having their visual design differ significantly may provide a level of defence against distraction.

Finally, remember the observation from Simons and Chabris (1999) that there is no perception without attention. Adding the practice of "touch and talk", or possibly "point and talk" when undergoing certain activities, particularly panel monitoring, will help ensure attentional shifts to objects. As shown in the Beanland & Pammer (2010) study, landing your eyes on something does not ensure your attention is actually on what your eyes fixated on. By talking about the display or device being fixated on and by pointing at or touching it you help "force" your attention to the subject. While research has shown you can look at something without focussing your attention on it, it is much harder to talk about it and target it with your hand without driving you attention towards it. Similarly, silently looking at an equipment code is less likely to fully shift your attention to the multi digit number than would reading it aloud while running your fingers underneath (or over) the letters and numbers as they are spoken. These possible practices only serve as examples of some possibilities in helping to ensure that the person's attention is fully engaged in the task at hand. To bring this back to the perceptual loading theory put forward by Lavie (1995), remember that any attentional resources not consumed by the primary task (reading the label or the display) will be "captured" by irrelevant or unexpected stimuli. The risk when performing very simple tasks is that so little attention is required for some tasks that the majority of attentional resources can be "captured" by other events reducing our performance on what is meant to be the primary task. The goal then is to actually increase the attentional demand of some of the low demand tasks (by speaking about it or pointing at it) such that while it may not consume all of the attentional resources it keeps the majority of attentional resources engaged on the primary task.

8. References

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