Engineering Psychology Course Pack
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Attention Vigilance and Fatigue

Attention

Arguably, attention is the most important area in Engineering Psychology. Without attention accidents occur more frequently, we are unable to process information and make decisions that impact our performance and the state of the system. A complete study of attention from both the psychology literature and the Human Factors literature could take more than a single chapter in a single course. In this chapter, we will briefly touch on some of the more pertinent topics in Human Factors.

One question that has always plagued psychological science is the question of how to study something that is difficult to observe. Psychologists have devised unique and peer reviewed methodologies to address this problem. One of the first psychology labs at University of Leipzig, Germany began with Wilhelm Wundt in about 1879 investigating sensation and perception <http://www.learner.org/series/discoveringpsychology/history/history_nonflash.html>. The history of psychology can be found here <http://apps.apa.org/StaticContent/timeline-assets/timeline.html>.

What is a construct in Psychology?

Unlike the other sciences such as chemistry, biology, or physics, psychological science cannot directly observe many of the things that it studies. Because of this lack of direct observation, we have to think of unique ways to isolate and measure the thing in which we are interested. Isolating something to be studied and then describing it in a way that can be studied is often referred to as making a construct. The thing itself is then called a construct because we are constructing a definition of what it is and what it is not and how it should be studied. In cognition, many of the things that we discuss are constructs. The first one that we'll discuss is attention.

What is attention? This construct is defined just as it seems. If they are processing the information presented, they are attending to it. If they are not processing it, they are not attending to it. We only know if someone is attending to something by their behavior during and afterwards. If they attended to the item, then they will be able to state that they noticed it, they will remember it, or they will behave as if they had noticed it.

Ways that we measure attention

In behavioral measurement experiments the person is shown the item or the scenario and then we measure if their behavior changes and how quickly it changes. Usually, attention experiments involve two tasks: a primary task and a secondary task. The person will be asked to do one item (primary task) such as ride a bicycle. Then, we ask the person to watch a screen for a stop sign (secondary task). In this task, the two tasks require two different types of actions. The primary task requires that the person coordinate their legs and feet to ride a bike. The secondary task requires that they look for something in the environment. We say that the two tasks are in two different modalities: physical movement and visual search.

Often the primary task is a task that many participants would do in everyday life. We might expect that participants would have no trouble with this task. This would be an initial control condition that would assure us that this is something that our participants could attend to easily. If we were interested in how

much attention was left over while doing a primary task, we would assign the secondary task at varying levels of difficulty. For example, we might have a few levels that increase in difficulty such as watching for a stop sign, watching for a pedestrian, and watching for a certain type of tree on the side of the road. If we were interested in additional processing capacity, we might add a third task of listen for the word MANGO while doing the first two tasks. This would partition attention and make it harder as people concentrate on doing all three at once. This is called the **dual task paradigm**.

It was experiments such as this one that led to the discovery that most of attention is a step by step or serial process. It also led to the discovery that people will select a primary task and do that very well. The secondary and tertiary tasks will suffer neglect as the person focuses on the primary task.

The dual task paradigm also tells us that people will switch which task is primary on their own in order to reallocate attentional resources. At the beginning of the study, the participant may ride the bike well and focus on maintaining a steady pace of 12 mph. Then, as the study progresses and several stop signs appear in rapid succession, the participant may focus on identifying the stop signs and the bike riding will slow down to 7 mph. If during the study, there are several stop signs in succession and then several incidents of the word MANGO on the headphones, the participant will struggle and may quit riding the bicycle. This is due to attention switching cost. Here is an example that you can try yourself <https://youtu.be/uz_zPZiUifs.

The other way that we know if someone has attended to something is through eye-tracking. If their gaze has been directed at an object and they have behaved as if they noticed it, we count this as attending to it. Eye-tracking is a very popular way to measure visual attention in psychology, marketing, and other fields. Here is a video that shows an eye-tracker being used. <https://youtu.be/ConsSlIf6n4

What does it mean to attend to something

Attending to something means that we have sensed the item that we were searching for or waiting for or something in our environment. If we are searching, then once we have perceived that this is the correct item or the target. Then, we respond. Attention requires all of these steps: sensing, perceiving, and processing. We know from studies that mistakes in attention can occur at any of these steps.

Back to the bike riding example. The participant can fail to sense the stop sign because there was too much interference in the environment (noise). This might happen when there is a tree partially covering the sign or another vehicle or pedestrian is passing and occluding the rider's vision. These would all be sensing errors that cause the item not to be initially seen. The rider would have the feeling that she never saw the sign at all because she did not.

In addition, the participant may see the sign but not perceive that it is a stop sign. This might happen when the sign is partially covered or when the light shines in a way that the identifying color, shape or word is mistakable for something else. Or, it might happen when the rider sees the sign but fails to recognize that it is the correct sign. Or, sometimes people see a similar sign and mistake it for the correct sign. All of these would be perception errors, she saw the sign but was unable to perceive it properly.

Finally, the most frequent error in attention happens at the processing stage. We may sense and perceive that it is a stop sign, but the primary task for monitoring for traffic signals may have become the second or third task and we fail to process the meaning of stop and fail to execute the behavior of stopping. Sometimes, this is called inattentional blindness. In this last item, this is what typically happens

in texting and driving accidents. Dr. David Strayer at the University of Utah has done groundbreaking work in this area. An overview of his work can be found here <https://youtu.be/yCD-brlpy7o>.

Automaticity and attention

Automaticity happens when a person does a task so often that it takes up very little of the attention bandwidth as in riding a bike and watching for a stop sign. Riding a bike takes very little of the person's attentional effort and is automatic. As the person rides, it is very easy to do other tasks that don't involve manipulating the bicycle. Watching for a stop sign also does not take up many resources as this is a task that is done frequently. So, watching for a stop sign and bike riding leaves room for other tasks as well. Eventually, a person's attention will be consumed and the person will be unable to attend to additional tasks. But, the person never knows which task will overwhelm the attentional system until it is too late.

I hope that you begin to understand why texting and driving is so dangerous. In many cases, a person may do this successfully as driving is an automatic task for many seasoned drivers. Monitoring the environment for traffic signals or for dangerous situations is also automatic. Drivers may choose to text when they feel that there is nothing that will demand their attention over what they feel is automatic. The accident occurs because driving is an unpredictable task. It is unclear when the outside environment will change because other humans are unpredictable. It is also unclear when the inside environment of the car will demand to be changed. Keeping the car system in concert with other drivers/cars, the environment, and the system stable is the driver's primary task. When a person texts, the primary task changes to the texting. This all works out fine if the systems remain constant, but once an unanticipated change occurs, the driver does not have time to switch primary tasks back to driving and an accident occurs.

What is task switching?

Task switching happens when a person has more than one task to perform and they change the primary task to the secondary. The cost in thinking time is miniscule, so people think that there is no thinking time associated with the switch. Experiments in the dual task studies have demonstrated that the time in measurable and builds up. For example, if you are studying and monitoring your phone for an important text message or alert, you are still studying. Each time you switch the primary task of studying to the task of picking up your phone, this attention switch costs a few seconds. If you compare the amount of information learned in this session to a session of only studying, there is significant information loss in the dual task session. In this way we know that task switching has a small but significant cost.

Additional terms to know

There are some additional terms that you should know. The first is **selective attention. Selective attention** is when you change your attention to focus on one area. Then there is **focused attention** that is when you select a particular item and attend only to it. Next is **divided attention**, this is when you were trying to attend to more than one item at once. **Sustained attention** is when you continue to attend to a particular item in your environment during a very long task.

There is also **multitasking**. This is when a person tries to attend to more than one item at a time. There is an invisible cost to multitasking. each time a person changes their focus there are a few milliseconds when the person needs to catch up it takes effort to move your attention from one item to another. This can be visual, auditory, or physical attention. Usually we think of attention as visual attention. Let's talk

more about attention just in terms of visual attention. When you attend to an area that area is called the area of interest or AOI.

Let's say you are watching the professor in class. The professor is in your **AOI or area of interest**. There are certain things that you expect the professor to do and there are certain things that you expect the professor not to do. When the professor does things that you expect, this helps your attention. If your attention is divided or you are multi-tasking and the professor does something that you don't expect you're more likely to miss it.

The professor will do things that are of high value or low value. She may tell you what will be on the test. This would be an example of a high value item that will grab your attention. The professor will do things that are low value. Maybe she is previewing the reading for next week and you already have read it.

There is a model that will predict when people will attend and will when they will not attend to a certain item. This is called the salience effort expectancy value model or **SEEV model** (Wickens, 2012; Steelman Allen, McCarley, & Wickens, 2011). According to the SEEV model when high-value items occur in a person's AOI and there is little effort that they must expend to attend to this item, then they will attend to it. If a high-value item requires effort to attend to it, then people are less likely to attend. Effort can be quantified by the amount of distance a person may have to move their eyes to see the item or the thinking effort that is involved (cognitive effort).

A few more terms to know- **change blindness.** This happens when a person has simultaneous tasks and miss something that changes in their environment. For example, they're taking notes in class and they are also listening to the professor. They are really concentrating on the notes. Let's say the professor is wearing black pants and a purple shirt and it is in the first week of class. The professor steps out into the hall for a moment and instead of the same professor coming in a different professor enters and continues the lecture with the same black pants and purple shirt and a similar voice. The majority of students will not catch that this is a different professor. There are multiple YouTube videos on this effect, one is here <https://www.youtube.com/watch?v=uO8wpm9HSB0>. Martens (2001) and Lee, Lee and Boyle (2007) are credited with much of the research in this area.

Inattentional blindness is another term that is similar to change blindness. Inattentional blindness should not be confused with change blindness as inattentional blindness happens when we see something, but we do not recognize it. This was found by Mack and Rock (1998). Inattentional blindness differs from change blindness in that inattentional blindness is the failure to see something that is there and change blindness is the failure to see a change that happens. Inattentional blindness occurs when we are texting and driving and see the traffic light change to red. As we are attending to three different set of things, the texting may be the current primary task that consumes most of our attention. We see the traffic light change but the meaning fails to prompt us to hit the brake pedal.

Visual search

Most of us are familiar with going through airport security and putting our bags through an x-ray machine. When we put our bags through this x-ray machine, a person searches for certain shapes and patterns in our bag. This would be an example of a **visual search**. In this case it would be called a **serial self-terminating search.** When the person who is viewing the x-ray screen finds something that looks like it matches the outline of a knife or some of the other banned items, that person stops the conveyor belt and that bag is set aside. Another officer takes that bag finds the person that owns the bag and then

goes through the items one by one. In this task the officer is searching for a target such as a knife or a gun among many distractors or non targets. An officer searches these items one by one. That's why it's called a serial search. When the officer finds a target such as a small camping knife, we say that the search is self-terminated because the officer believes that he has found a banned item.

There are other types of searches as well. There is an **exhaustive search** that's when the person searches all items in the field. Sometimes you are looking for individual features that are present together in one item and sometimes you are looking for the absence of a certain feature in the area of search. The literature surrounding visual search is based on the idea that we process things in a bottom-up or a top-down fashion. Here is a page that explains the difference between bottom up processing and top down proccessing <http://openpsyc.blogspot.com/2014/06/bottom-up-vs-top-down-processing.html>.

Auditory Attention

For both visual and auditory items, we have a very short term storage area that collects and saves the sensations for us to select what we want to process and what we want to discard. For visual items, this is the iconic store. For auditory items, this is the echoic store. Both the iconic and the echoic memory stores last for between 2-6 seconds for most people. During this time our long term and short terms memory storage areas will also interact with the iconic and echoic storage and sometimes help us select the most important sensations to process. When we store things for this short amount of time, we are usually unaware of them. So these storage areas are called pre-attentive or before attention can engage and we can consciously be aware of what we sensed. There is some pre-attentive processing. We know this from experiments with auditory attention.

Just as with visual attention, in auditory attention experiments, the participants have a primary task and a secondary task. Usually, participants wear headphones where the right ear and the left ear hear different things. This is called the dichotic listening task. A person may be listening to a conversation in one ear and then monitoring the other ear for a certain word. If that word is very meaningful to them (i. E., their name). Then, they are much quicker to respond. In fact, there is a phenomenon called the cocktail party effect which describes how this happens in real life.

Lets say that you are at a large party with friends. You are having a good time when you hear someone in the far corner say your name. Regardless of the amount of noise, you will be able to exclude it and hear parts of that far conversation where your name is used because of the importance of your name to you. This is called the cocktail party effect. Just as in a busy cocktail party with many people talking, important information is easiest to selectively attend to when it involves your name.

In addition to sensory paradigms such as auditory and visual tasks, there are cognitive attention tasks such as proofreading a paper or monitoring for a particular word or phrase on a screen. There are also proprioceptive and haptic tasks. Proprioceptive tasks are ones in which you monitor your body for a shift in its balance or the space that it occupies. A haptic task is when you monitor for the change in a control or touch pad.

Detection Rates

Sometimes people will be more or less sensitive and detect a change more or less easily. We call this difference in detection rate bias. Bias can be modeled through signal detection theory where the number of correct targets found is the hit rate. The number of false targets identified is the false alarm

rate. The number of targets not found is the miss rate and the amount of noise ignored is the correct rejection rate. A ratio of these numbers helps us to estimate accuracy and bias in a search task or any performance task where a novice is compared to an expert.

We know that several things in addition to attention affects a person's hit rate or their ability to find a target when there is one. The intensity of a target, the value of the target, and the duration of the target all can interact with a person's bias to determine whether a target will actually be found or not. For example, lets go back to the airport security visual search task. Let say that each time an officer searches the X-ray screen for a knife and thinks that there is a knife in the bag, the officer gets a tiny raise in salary. If the officer sees the knife on the screen and then a subsequent bag search finds a knife, the officer gets a larger tiny raise in salary. The officer is more likely to identify things that could be knives in the hope that one of them actually is a knife. There is no penalty for an incorrect identification or a false alarm.

Now, to demonstrate bias, lets say that for the same task, the officer gets a pay decrease each time the officer states that there is a knife and a bag search does not produce a knife. The officer gets a pay decrease for wasting the traveler's time and humiliating her in front of her fellow travelers. This officer's search bias will be more conservative and the officer will be less likely to identify a knife unless there is enough evidence and the officer is fairly sure that one will be found. In the first instance, the officer is biased to produce as many hits and false alarms as possible because there is no penalty for a false alarm. In the second instance, the penalty is steep, so the officer produces as many hits while avoiding as many false alarms as possible.

Imagine that this is your job, to be an airport security officer and monitor the x-ray screen and search bags. Lets imagine that one shift is four hours. For four hours you will be watching the bags go across the screen and you will be picking out knife and gun shaped objects. By the end of four hours do you imagine that you will be producing more hits or more false alarms? You're right, it depends on how many targets you correctly identify and how much practice you have at this task. In general, your ability to produce hits will decrease the longer you are on the job at this vigilance task. A vigilance task is a task that requires a high level of attending for a long period of time, usually over an hour. As time passes in this task, you become tired or fatigued. Your sensitivity decreases. Your fatigue will increase as the task gets more difficult or the pace of the task picks up.

As a security officer, your sensitivity rate will be far higher if you work a four hour shift when there are only three flights out of the airport compared to your colleague who works a four hour shift when there are forty flights out of the airport. This is also called Sustained Demand Theory (Parasuraman, 1979; Matthews, Davis, & Holley, 1990). There are some things that can be done to help address fatigue during a vigilance task.

One way that has been implemented recently is to increase target noticeability. The next time you fly, if you peek behind the x-ray machine to the screen that the officer views, you will notice that there are green, yellow and red outlines showing up on the screen. The newer x-ray machines incorporate machine learning to predict shapes of knives and guns at various angles within suitcases. If there is a pattern in the bag that matches one of these angles, a red outline of the shape will appear. This reduces fatigue in the officers by helping them in the visual search task through increased target noticeability and highlighting possible examples.

Another way to address fatigue in these officers is through a knowledge of their results. Was that odd shape really a knife or was it an odd shaped comb? The knowledge of how may hits and false alarms help the officers improve their hit rate as they learn the shapes better. There are additional ways to increase sensitivity and appropriately setting the criterion level as to what should be a hit and what is a false alarm. These include better instruction, an accurate estimation of the probability or co-occurrence, and shorter work periods. It is important to note that vigilance tasks also suffer when a human's internal state is not optimal. In other words, it is hard to pay attention when you are tired, hungry, bored, or unmotivated. Finally, the higher the workload or the more difficult the task, the shorter the period of work should be.

Under arousal

Just as important are tasks that are so simple that the operator is bored while she waits for the important parts of the job to happen. When there is much time between events, the miss rate goes up and the hit rate decreases. When the value of the target is low, again the operator will be bored and the miss rate will increase. Finally, when the target is difficult to detect, infrequent, and under valued, the operator will find it difficult to monitor for the target and maintain vigilance.

Conclusion

Visual and auditory search can begin in the pre-attentive phase when the sensations are still in iconic and echoic memory stores. In visual search, a person can use a top down approach (i. e. a gun has a barrel and a trigger- so does this shape so it must be a gun) or a bottom up approach (i. e. this shape looks like a trigger, is there a long cylindrical piece attached). A person can use a serial self terminating search, parallel search , contingent search, or various other methods of searching depending on the goals of the search and what is item is searched for and where it is being searched. In auditory search, a meaningful word can trigger a selective attention mechanism. Detection rates can be quantified by the number of targets identified, the number of targets not identified, the number of items falsely identified as targets and the amount of non targets ignored. This ratio can predict bias in the searcher and predict changes in bias and selection criteria based on external motivators or conditions during the search. It is possible to be overwhelmed and experience difficulty in maintaining attention or vigilance. It is also possible to be underwhelmed and experience the same difficulty. Attention is the first part of information processing and therefore is key in understanding how humans sense and perceive a system and its tasks.

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