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Conscious awareness: Linking our experience of the world with the functioning of our brains

This chapter is the first in a series of chapters devoted to specific topics. We begin with a discussion of conscious awareness. This topic is fundamental to how we think about the roles of humans within systems. Often implicitly, our systems' designs assume that humans are consciously aware of their actions and are operating in a knowing manner, cognizant of what they are doing and why they are doing it. We exhibit a bias to assume conscious awareness in interpreting the actions of others, and with our own actions, as well. It is unsatisfying to think that a person might have no explanation for an erroneous action. Likewise, it is hard to accept that the logic on which we base our beliefs might often reflect an after-the-fact rationalization. This is understandable given that we experience life through the medium of conscious awareness and have limited access to those processes and knowledge that exists outside of our conscious awareness. In filling our roles as designers, engineers, analysts, managers, or otherwise, there is value in recognizing the extent to which our assumptions regarding conscious awareness shape our thinking, and often, make us vulnerable to certain biases, as well as the influence of others. One of the major trends within brain science over the past decade has been a growing recognition of how little we are aware of the operations of our brains, and that the overwhelming majority of what happens within our heads occurs at the largely inaccessible level we think of as the unconscious (Custers & Aarts, 2010; Vedantum, 2010).

Unlike other parts of the body that are richly endowed with sensory receptors, we have no practical mechanisms that allow us to sense and experience stimuli arising from the tissues that make up our brain. The surface of the body is covered with tactile (i.e. touch) sensors. The muscles and joints possess sensors that are responsive to their motion and relative position. Pain sensors occur throughout the body providing unpleasant sensations when exposed to destructive or noxious stimuli. In contrast, our primary sense of the brain comes through conscious self-reflection. Yet, this reflection tells us little about the operations of the brain. It mostly offers a glimpse of our memory as occurs when we visualize things we have seen, or recollect something we have heard or felt, or construct scenes within our heads. Additionally, we have some measure of control over the internal voice that enables us to think and annotates our conscious experience of the world with a verbal dialogue. In general, we lack a direct sense of our brains, with our conscious experience, and self-reflection, being more of a product of the operations of our brain than a direct sensory sensation of our brain.

This distinction between the conscious mind and the unconscious brain is important because it is central to the ways that we think about ourselves and others. Our conscious minds create the sense that we have control of our actions, and to a large extent, our thoughts, and we generally approach the world as if this is the case. Likewise, we assume the same with others, and assign responsibility to them for their actions, and thoughts. When we interact with others, we experience it as an interaction between two conscious minds, with each participant in the interaction being responsible for what they say, think and do. Similarly, when we observe the actions of others, we assume they are consciously aware of what they are doing and their actions are intentional and deliberate. These are biases that are deeply engrained that shape our perspective on the world, events, others, and even ourselves.

Of the many mysteries housed within our brains, there is probably none other that has been more elusive than conscious awareness. Cognitive neuroscience cannot explain what conscious awareness is, how it happens or what function it serves. However, to the extent that conscious awareness can be parameterized and measured, cognitive neuroscience can speak to the coincidental brain processes and shed light on how to more or less effectively engage humans in various activities.

Conscious versus non-conscious engagement

We frequently have experiences that reveal the presence of our brains operating alongside and in parallel with our conscious experience of the world. In an exercise I routinely do during classes, I ask everyone to raise their hands, and instruct them to consciously not think about anything and when the first thought pops into their heads, to lower their hands. Most lower their hands in the first few seconds. Very few are able to make it past twenty seconds with these generally being individuals who practice meditation and have some familiarity with trying to clear their mind of the ongoing stream of thoughts. This exercise demonstrates that despite a conscious attempt to quiet the internal voice emanating from our brain, we can only do so for a brief period of time. I like to say that, "the mind influences the brain, but it cannot control the brain."

There are many other situations familiar to us all that illustrate the limits of our conscious mind's ability to control the brain. For instance, we may attempt to focus our thoughts and attend to our surroundings or tasks in which we are engaged, yet without warning, often without our even realizing it, our mind wanders and we begin to think about something else. This is particularly true when something is bothering us or we are worried about something, and despite our efforts to ignore it, or let it go, we cannot suppress the intrusive thoughts, which repeatedly emerge. Here, we know what we want to do, or actually, what we want our brain to do, but our brain seems oblivious to these intents and does exactly what we do not want it to do. Not only that, some time may pass before we realize that we have slipped, and have become consumed with the thoughts we had sought to suppress.

When engaged in a task that requires some degree of concentration (e.g. reading) or sustained attention (e.g. driving), we may tell ourselves to ignore surrounding distractions. However, certain sensory events capture our attention. For instance, while sitting on a train trying to focus on the book or paper we are reading, it can be effortful, if not impossible, to ignore an intriguing conversation nearby. When drowsy, we may try to stay awake, but under the right conditions, despite our best intentions, we still fall asleep. Maybe it is a sign of an aging brain or just absentmindedness, but it is a personal struggle for me to get out of the house without forgetting something. I tell myself to not forget and may even place items by the door so that I will see them as I am walking out, but to my undoing, I become distracted and forget. Similarly, when I need to do something that is outside my ordinary routine, such as making a stop on the way to work, I am as likely to become distracted and forget as I am to remember. The conscious mind has goals and intentions and we like to think of ourselves and others as purposeful, goal-directed beings. But not only are our brains prone to distraction, the conscious mind may not realize that the brain has gotten off track until it is too late to recover and you are left to undo what the unconscious brain has done.

Slips of the tongue are particularly interesting. In our conscious mind, we know what we want to say. But, then the words we hear come out of our mouth are not the words we had intended to say. Usually, it is explainable in that the slip corresponds to something that we had recently been thinking. Prior to any action, whether speech or otherwise, the brain makes preparations to carry out the act. These preparations have been likened to a software program with programs containing signals necessary to elicit appropriate muscle activity (Adams, 1971). With slips of the tongue, it is believed that the brain simultaneously prepares multiple programs, yet executes the wrong program (Moller et al, 2007). This was illustrated in a study by Moller and colleagues (2007) in which subjects were induced to commit a certain type of slip of the tongue known as a spoonerism. With a spoonerism, one swaps the positions of words within a sentence. For example, instead of saying, “Go and take a shower,” one might say, “Go and shake a tower.” In trials in which a subject committed a spoonerism, there was increased activity in supplementary motor area of the brain. This brain region is believed to serve as a buffer that holds prepared motor programs until it is time for their execution. It was suggested that the increased supplementary motor area activity prior to committing a spoonerism reflected the activation and competition between multiple motor programs. The anticipatory preparation of motor programs represents a mechanism to increase the efficiency of brain function. This is evidenced by faster reaction times when a subject is able to anticipate and prepare for a forthcoming motor action (Kerr, 1976). The preparation often occurs at an unconscious level and is a product of environmental cues that prime the brain, generally enabling it to be more responsive. Within an engineering context, at an unconscious level, designs that present ambiguous or competing cues prompt the brain to simultaneously prepare multiple programs for carrying out alternative actions. This ambiguity heightens the level of demand imposed upon the brain as it must suppress the inappropriate action while carrying out the appropriate action. The competition between competing actions may occur entirely outside of conscious awareness, yet the effects may be felt at a conscious level through the level of effort required to complete certain tasks.

With slips of the tongue, there is a certain helplessness that arises when we witness our brain and body operating in a manner that is contrary to our intentions. Nothing makes the division between the conscious mind and brain clearer than these experiences. Our brain has the capacity to operate autonomously, and sometimes actually seems to assert this autonomy, blind to the consequences of its missteps. At the same time, our conscious mind seeks to curtail that autonomy, and direct our brain. However, no matter how much we try, we eventually slip and the brain does what it wants to do.

Vulnerabilities that arise due to the limits of our conscious awareness

It is important to understand the distinction between the conscious mind and unconscious brain because during our everyday experiences, we are constantly receiving messages, whether through our interactions with other people, the materials we read or watch, or our experiences with objects, devices, and even physical spaces. Some are directed to our conscious mind and some are directed to our unconscious brain. A certain image may be used in an advertisement because it is likely to illicit an emotional response. A certain policy or procedure may be put in place because it forces people to slow down and think about what they are doing. A device may be constructed so that it creates a certain feel when we hold it in our hands or produces a certain sound when activated. Whether done knowingly or unwittingly, messages are generally tailored in such a way that they influence and engage either our conscious mind or our unconscious brain. Likewise, as we interact with others, we are doing the same. We may not always know that we are doing it, or mean to be doing it, but the words we use, the courses of action that we select and the ways in which we structure and manipulate the world around us influences others. Sometimes we seek to engage the conscious minds of others, and other times we seek to engage their unconscious brains. I believe that in the same way that it is pertinent to ask, “Are you talking to my mind or my brain?” when scrutinizing other’s attempts to influence ourselves, it is similarly pertinent to ask, “do I want to speak to their conscious mind or their unconscious brain?” when we seek to influence the thoughts and behaviors of other people.

The following sections describe several factors that determine whether a message will have a greater effect on the conscious mind or the unconscious brain.

Sense of urgency

The mechanisms that engage the conscious mind are very different from the mechanisms that influence the unconscious brain. For instance, the unconscious brain can be impulsive and take actions without considering the potential consequences. In contrast, the conscious mind can appreciate delayed gratification and weighing the consequences of alternative actions, keeping us on track to achieve long-term goals. If we want to engage the unconscious brain, we create a sense of urgency and insist that a decision must be made immediately. We regularly experience this when we see advertisements or interact with salespeople that emphasize limited time offers, where if you do not do it now, you may never have the chance again. In contrast, the conscious mind is able to envision a future where by waiting, you get more or have a better overall experience or avoid negative consequences.

Placed in a situation in which we are being encouraged to take some action, particularly when it is an attractive option, the corresponding action is primed within our brain. Whether or not you actually commit the act, at an unconscious level, the brain prepares to do so. An effective salesperson may not only suggest that you buy their product, but they will present a pitch that causes you to imagine yourself going through the actions of making the purchase. At an unconscious level, this process of imagining yourself taking the desired actions, primes those actions within the brain. This priming may be observed as increased activation in two brain regions (Fortsmann et al, 2008). One is the supplementary motor area discussed previously in relation to the formation of motor programs. The second is the striatum, which functions to map patterns of cues in the environment to specific actions (Wan et al, 2011). Normally, there is some threshold of activation that must be exceeded before an action will be taken. Consequently, as we go through the world constantly being primed to take various actions, we are able to resist these temptations in favor of the intended action (e.g. passing a row of vendors with various foods on our way to the restaurant where we plan to have lunch). While tempted (i.e. primed at an unconscious level), activation does not exceed the threshold for us to take action. The capacity to resist temptation and withhold a response is a product of inhibitory mechanisms within the brain that serve to suppress competing actions, preventing the corresponding activation from surpassing the threshold that would produce action, as we carry out our intended action.

The effect of time pressure has been demonstrated in experimental settings that ask subjects to make decisions where a better decision will be made if they take longer to make the decision. For instance, subjects may be asked to identify an image as details of the image are slowly added. Obviously, a more accurate decision will be made if the subject waits until more details have been provided. Similarly, if subjects are asked to trace a complex figure, their tracing will be more accurate if they take longer to do it. In these settings, subjects may be cued to emphasize either speed or accuracy. When subjects are cued to emphasize speed, there is increased activation of the supplementary motor area and striate, indicating a reduction in inhibitory processes that might normally be operating on these regions (Forstmann et al, 2008), accompanied by an increased emphasis on preparatory processes. In contrast, when subjects are cued to emphasize accuracy, there is a reduction in activation suggesting greater involvement of inhibitory mechanisms, accompanied by increased monitoring of ongoing actions.

Whereas the unconscious brain is prone to impulsive action, our conscious brain often serves to supply an inhibitory influence, keeping the impulses of the unconscious brain in check as we focus on our goals. Time pressure and the associated sense of urgency can have the effect of not allowing the time necessary for the conscious mind to exert its normal inhibitory influence, causing us to act more impulsively. Thus, to engage the conscious mind, you want to insist that there is time to think and that there is no need to make an immediate decision. Although, it should be noted that whether you are better off relying on your conscious mind or unconscious brain is not always certain. Often, opportunities are limited and in these situations, the deliberations of the conscious mind can be counterproductive and lead to stagnation, missed opportunities and responses that occur too late to produce the desired effects.

Appeals to logic

Within Western cultures, where tremendous value has been assigned to logical thought, the conscious mind is predisposed to favor deliberative analytic approaches to interpreting events and making decisions (Nisbett et al, 2001). It is engrained into those of us in the West that when posed with a problem, we resort to detailed analysis and apply logic to reach a solution. This is what we have been taught that we ought to do. These mental operations are the hallmark of the conscious mind and it has been hypothesized that the capacity for logical thought is one of the factors that promoted the evolution of conscious awareness within humans (Baumeister & Masicampo, 2010). Consequently, when seeking to engage the conscious brain, one should emphasize appeals to logic that are rotted in facts, statistics and data.

In contrast, the unconscious brain is not predisposed to favor rational thought and is susceptible to appeals based on emotion, sentimentality, stereotypes and fear. Within Western cultures, these are influences that are looked down upon and treated as weaknesses because they interfere with logical thought. However, emotion allows the brain to almost instantaneously interpret situations and recognize what type of behavior would be appropriate (LeDoux, 1996). When someone knocks at your door in the middle of the night or you walk into a room and are overwhelmed by a disgusting smell, emotions allow you to quickly narrow down your choice of responses, and take action, with little or no thought.

Stereotypes can be unfair, harmful and offensive, but there is a reason why the brain is prone to stereotypes. Events can be overwhelming, flooding the brain with more data than it can process. It can become impossible for the brain to individually assess every detail. The brain copes by categorizing so that once something or someone is assigned to a category, everything you know about that category can be attributed to that object or individual (Stevens et al, 2007).

Obviously, it becomes problematic when attributes are erroneously associated with a category (e.g. a certain type of person is assumed to always be lazy or dishonest), or categories are applied too broadly allowing people or things to be falsely lumped together (e.g. all vegetables taste bad or all documentaries are boring). However, without this propensity for categorization, the brain would be incapable of coping with the complex world in which we live.

There are many things that brains just do. You may not intend to do it. You do not think about it. Your brain just does it. Categorization is one of them. But there is a reason the brain does these things. Otherwise, it would be incapable of handling the complexities of human existence. Furthermore, the brain is usually right. Yet, the brain sometimes gets it wrong. This makes us vulnerable, whether it is to our tendency to overgeneralize or to the attempts by others to influence us by appealing to false generalities (i.e. stereotypes), particularly those associated with strong emotions (e.g. racial prejudices), whether it is done intentionally or as sometimes occurs, unknowingly.

Distraction versus solitude

To deliberate and carefully analyze situations, the conscious mind needs an environment free from distractions. The conscious mind is best engaged when offered the opportunity to operate in solitude. When we want to collect our thoughts, we find a quiet room or go for a walk. In contrast, if we want to engage the unconscious brain, we present various distractions. We make it hard to sustain a continuous train of thought. We introduce competing demands so there is more than one thing to do. We pose some level of threat so that one must contend with the distractions that arise from internal worries and anxieties.

The brain is designed to be sensitive to changes in our environment and an involuntary response is generated when exposed to either a novel stimulus or an unexpected change in an ongoing stimulus. For example, using the simple task of discriminating even from odd numbers, it was found that reaction times were slower on trials in which an expected background tone (i.e. occurred for 80% of trials) was substituted with a natural sound (Alho, Winkler & Naatanen, 1998). Longer reactions times were accompanied by a pronounced neural response in the timeframe 200-300 msec following the unexpected stimulus. Interestingly, in this same study, on some trials (i.e. 10%), the investigators substituted the standard tone with a similar tone, but of a slightly different frequency. This deviant tone did not generate a novelty response and did not slow reaction times, but produced a reduction in accuracy for the odd-even number discrimination. The response of the brain to the deviant tones could be seen as a spike in activity at approximately 150 msec following the stimulus. Based on these results, it was concluded that the brain possesses two somewhat distinct mechanisms that involuntarily respond to unexpected stimuli within the environment. One responds to novel stimuli while the other responds to changes to an ongoing stimulus. An involuntary response due to either of these mechanisms draws upon our limited resources and makes it more difficult for the brain to exert the effort required to consciously focus one's thoughts and attention.

The environment and associated experiences we create will influence the extent to which we engage the conscious mind or the unconscious brain, of both ourselves and others. For instance, there may be situations where for good reason, we do not want to engage the conscious mind. We may want to take a break from whatever weighty matters have dominated our thoughts and allow the brain to take us where it will. Nothing accomplishes this goal better than to immerse ourselves in a busy, noisy, crowded situation. I have always found that there is a strange but satisfying sensation that comes from walking the streets of a busy city or the multi-sensory experience of a carnival midway. In these environments, every type of sensory stimulation comes at you from every direction, there are people all around and everywhere you look, there is something different for you to experience. The unconscious brain thrives in this type of environment and it can be a welcomed break after a period of prolonged concentration.

Simultaneous messages

If you want to engage the conscious mind, perhaps we want to convince someone that a certain position or activity or set of priorities is in their best interest, it is important to present a single, clear and distinct message. You do not want to confuse them and have them thinking about one thing, then another and not seeing how different ideas fit together. If their conscious mind cannot latch onto your ideas and most importantly, begin to operate on them, whether linking to other ideas, appraising the pros and cons, restating your ideas in their own words, etc., one of two things is likely to happen. Their brain will react to some superficial, unintended facet of what you have said and your message will be misinterpreted, or their brain will drift and they'll never hear your message. It is important to never overestimate the capacity of others to consciously attend to what you are trying to communicate to them. They may have the best of intents and want to give you serious consideration, but if your message is obscure or scattered so they themselves have to put the pieces together, this may demand more conscious effort than they are willing or able to exert on your behalf.

Our brains are constantly the target of messages. Whereas the conscious mind operates best with a single distinct message, the brain can process several simultaneous messages, including the subtle and nuanced implications embedded in these messages. The brain effortlessly processes and reacts to this content, but often, you are not consciously aware of it. For instance, most popular web pages contain advertisements and our general sense is that we effectively ignore them. However, it has been shown that after being exposed to web ads, despite being unable to recall having seen specific ads, subjects reported being more favorably disposed toward the products (Yoo, 2008). Additionally, when asked to generate the names of products, subjects were more likely to list the brands that had appeared in the web ads. Both intentionally and unintentionally, others are influencing us through messages affecting our brains, without our realizing it. This might involve attempts to directly prompt a response (e.g. steer you toward an impulsive purchase), as well as efforts to induce us to bypass the thoughtful considerations of the conscious mind (e.g. appeals to sentimentality or prejudices).

There are two common approaches used to subvert the conscious mind, and engage the unconscious brain. The first involves bombarding you with multiple simultaneous messages which takes advantage of the conscious mind’s inability to process more than one message at a time and the brain’s capacity to simultaneously process multiple messages. This occurs when a magician diverts our attention in one direction so we do not see other activities key to the illusion. This occurs where numerous sensory cues are used to create certain experiences as occurs at amusement parks, fun houses, and theme-oriented restaurants. This also occurs at a protest, rally or similar event where signs, slogans and other messages converge to amplify one another, evoking stronger sentiments in the crowd than exist in all, but a few of the more extreme participants.

A second common approach to affect the unconscious brain, while bypassing the conscious mind, embeds triggers within messages that will provoke a response from the brain, whether through subtle suggestions, hidden associations or even subliminal content. In the case of racial prejudice, it has been shown that following extremely brief exposure (30 msec) to images of faces, within the amygdale, which is a brain region sensitive to stimuli that arouse emotions, there is heightened activity when the face is a member of a racial outgroup (e.g. White Americans viewing images of African Americans), as compared to faces of individuals from a racial ingroup (Cunningham et al, 2004). In crafting a television commercial or print advertisement, actors and models are selected because their appearance conveys the desired message or because targeted groups will relate to them. Specific words will be used in a slogan or other frequently repeated messages because they both convey the primary idea, but also because of their association with other ideas, which may include ideas that it would be unacceptable to openly express (e.g. subliminal appeals to racial prejudice). With either approach, the outcome is the same. Your thoughts, ideas and behavior may be affected without you being consciously aware of the influence others have had upon you.

The unconscious brain can be easily influenced, however many of us might not be alive today if not for the capacity of the brain to process simultaneous messages without our conscious awareness. When driving and another vehicle unexpectedly pulls out in front of you, there is not time for the conscious mind to process this situation and decide how to react. Instead, the brain instantly responds, and we slam on the brakes. Afterward, the mind has to catch up and we become consciously aware of what we have done. While extreme, this example illustrates how beneficial it can be that our brain is constantly taking in sensory input and responding to it, without our being consciously aware of it.

Personal relevance

To engage the conscious mind, you must first get its attention. Imagine you are in a busy place where there are many people talking at the same time, such as a party or a crowded restaurant. If someone says your name loud enough for you to hear it, it immediately captures your attention. It is amazing that one word (i.e. your name) embedded within one of perhaps a dozen conversations will prompt an immediate, involuntary response. As your brain processes the many signals coming from various sources, the brain is particularly sensitive to those that have personal relevance, with there being few signals that have more personal relevance than your name. When we hear our name spoken, there is a combination of brain regions that exhibit heightened activation with these being areas associated with speech processing (superior temporal gyrus), one's sense of self or self-consciousness (precuneus) and the monitoring and control of actions (medial prefrontal cortex) (Perrin et al, 2005). The broader implication is that messages that have personal relevance will be more likely to capture your attention and consequently, will have preferential access to your conscious awareness.

To engage the conscious mind, messages should be made personally relevant. While gratuitous acknowledgements can be awkward, there is no more direct way to get someone's attention than to mention their name, ideas, accomplishments or similar personal associations. In fact, merely creating an expectation that there will be a personal reference is often enough to assure that you'll have their attention. The same effect may be achieved by mentioning places, institutions, people, beliefs or other references that have personal relevance. In general, to elicit the thoughtful consideration that is the hallmark of the conscious mind, an individual needs to sense that a message is personally relevant to them, with appeals based on personal gains or losses being particularly effective in capturing one's attention.

Two separate cortical networks have been described that mediate the response of the brain to stimuli based on their personal relevance (Schmitz & Johnson, 2007). The first network (the ventral-medial prefrontal cortex-subcortical network) anticipates stimuli that are personally relevant and orients attention toward these stimuli. Accordingly, at a pre-attentive (i.e. unconscious level), the brain senses situations that have the potential to be personally relevant and focuses attention on those situations. The second network (the dorsal-medial prefrontal cortex-subcortical network) engages introspective processes, which may involve self-reflection, evaluation or recollection. Presented personally relevant stimuli, this network operates at a conscious level evoking thoughts that establish and elaborate the personal connection to ourselves. Generally, these networks operate in parallel with the former capturing our attention and the latter establishing the personal relevance.

Appeal to the herd

To engage the unconscious brain, you do not want to provoke conscious deliberation, but instead, take advantage of the fact that at an unconscious level, the brain is constantly sensing and being influenced by the world around us. Whether we know it or not, we sense what the people around us are saying and doing, with there being a tendency to mirror what we see in our own actions and what we hear in our own thoughts (Chartrand & Bargh, 1999). This tendency to mirror others has been linked to the brain's "mirror neurons" (Iacoboni, 2009). These neurons, and their corresponding circuits, are particularly active during situations when an individual is watching another person perform an action, and especially, when the objective is to imitate that action (Rizzolatti, Fogassi & Gallese, 2002).

At an unconscious level, our brains register the actions of others and exhibit a propensity to imitate those actions. Historically, charismatic leaders have sought to influence the populous through expressions of attitudes, beliefs and calls to action during mass gatherings. Today, the prevalence of various media create countless mechanisms by which we are similarly being influenced with the brain willing to transfer the positive affect we associate with celebrities, and other popular individuals or groups to various products, activities and causes (Stallen et al, 2010). The unconscious brain is susceptible to activities that have the effect of creating a sense that there is a trend or fad, or that everyone is doing it, or saying or thinking it. Appeals to the herd can have an inexplicably powerful effect and as chronicled by Charles MacKay in his classic book *Extraordinary Popular Delusions and the Madness of Crowds* (MacKay, 1841), in retrospect, these attitudes, beliefs and behaviors may seem irrational, and perhaps even silly. Yet, during most of our endeavors, the propensity for mimicry is highly adaptive allowing us to effortlessly learn mechanisms for coping with the complexities of everyday life. Actually, the herd is usually right. For example, online recommendations based on the popularity of songs, movies, etc. are usually fairly good. Fortunately, our brains seem to appreciate the wisdom of the crowd. However, it should not be forgotten that sometimes the herd is gullible, and may be steered in directions that are irrational, or perhaps even harmful.

How do the pros do it?

In discussing the distinction between the conscious mind and unconscious brain, I like to show one or two well-made advertisements from television and invite the class to debate whether the intent is to engage the conscious mind or the unconscious brain. One of my favorites is a public service announcement developed for the Canadian Broadcasting Corporation featuring the "house hippo." By searching YouTube for "house hippo," you should be able to easily find it. The commercial begins with the narrator's voice speaking in a deep, serious tone typical of a documentary as the camera pans a darkened kitchen with an observant cat sitting on the floor. Then, there is the faint outline of an animal scurrying mouse-like across the floor. However, when the image becomes discernable, it is a miniature hippopotamus. It stands in a grazing posture with a pet's water bowl in the immediate background as the narrator provides a descriptive account wherein the house hippo lives in homes surviving off scraps of food. Subsequent images have the house hippo showing its teeth and backing off the house cat which towers over it, swimming in a pet's water bowl and building a nest of threads and lint.
Before the conclusion, which reveals the intended message, I pause the video and ask for opinions as to whether the objective had been to engage the conscious mind or the unconscious brain. There is usually a range of responses. Some will say, "mind," and emphasize that the fact it could not be real makes you rationally contemplate the message. Others cite the cuteness of the miniature hippo as an appeal to the same feelings invoked by baby animals and contend that the intent is to engage the unconscious brain.

Either answer is correct. There are facets of this commercial that target the conscious mind and others that target the unconscious brain. In delivering a message, it is not always necessary to select either the conscious mind or the unconscious brain as your target, but a thoughtfully-crafted communication may target both. For instance, I believe that the house hippo commercial begins by using surprise (i.e. the animal scurrying across the floor unexpectedly turns out to be a hippopotamus, instead of a mouse) and the cuteness of the miniature hippopotamus to engage the unconscious brain, and get the viewer's attention. Afterward, the improbable nature of the subject engages the conscious mind and causes the viewer to think. The commercial ends with a second narrator saying, "That looked really real, but you knew it couldn't be true, didn't you. That's why it's good to think about what you are watching on TV and ask questions, kinda like you just did." Then, we learn that the message is a product of the Concerned Children's Advertisers. This is only one of many strategies that combine mechanisms to engage the conscious mind with others to engage the unconscious brain. To be effective in our interactions with others, it is important to consider how to best communicate our message, whether by targeting the conscious mind, unconscious brain or both, and craft our messages accordingly.

Timing of brain processes and conscious awareness

In 2008, John Dylan Haynes and colleagues at the Max Plank Institute reported a study in which they asked whether the conscious mind can actually keep up with the unconscious brain, and in essence, whether our actions are truly the product of conscious intentions (Soon et al, 2008). We all have the sense that our intentions to do one thing or another arise from our conscious mind, and assume the same for others, holding ourselves and others responsible for the resulting actions. We say that someone was consciously aware of a decision and knowingly acted with the intention to produce a certain outcome.

In the study by Haynes and colleagues, the subjects were given two buttons to press and asked to press one or the other every so often. Thus, it was the subjects' decision when to press a button and which button they would press. Additionally, during this time, a series of numbers were presented and subjects were asked to report which number appeared at the time they made the decision to press the button. During this time, the subject's brain activity was recorded using an fMRI. Using statistical techniques, the researchers identified distinguishable patterns of brain activity that corresponded to the subject either pressing one button or the other. Thus, having identified patterns of brain activity associated with pressing each button, the experimenters could accurately predict which button the subject had decided to press based entirely upon the activity of the subject's brain.

Subjects reported the number that was displayed at the time they were first aware of having made the decision to act. If the decision to press one of the buttons had been a product of a conscious choice by the mind, then the brain activity associated with choosing the selected button should have appeared at about the same time as the number the subject reported being present when they made the decision to act. Instead, the brain activity preceded the reported number by approximately seven seconds. This suggests that the brain had begun preparations to act seven seconds before the mind became consciously aware of it. Actually, if you factor in the delay that is inherent in fMRI recordings of brain activity, there was almost a ten second delay between the point in time that the brain began its preparations and the point the subject was consciously aware of the brain's intentions.

We have all had experiences equivalent to the one created by the experimental procedure Haynes and colleagues employed. When slipping on ice, the brain instinctively responds by extending the hands to catch ourselves before we hit the ground. Afterward, there is a moment of confusion and disorientation as the conscious mind catches up and then, we realize what has just happened. Similarly, when we automatically slam on the brakes of our car to avoid an accident, it is only after a moment of thought that we put the pieces together to make sense of what had just happened. Another related example occurs with slips of the tongue where we intend to say one thing, but catch ourselves saying something different. These examples illustrate the momentary delay between when the brain reacts to a situation and the mind becomes consciously aware of it. However, each of these examples also involves a situation that either demands immediate action or is somewhat spontaneous in nature (i.e. the give and take of everyday speech). Most of our actions play out over a longer period of time allowing an ample opportunity for the conscious mind to recognize what the brain is doing and if necessary, intervene before the action actually takes place. In fact, in the report by Haynes and colleagues, they emphasize that while there may be a delay between the decision to act and conscious awareness of this decision, one is generally quite capable of interrupting before having acted on an ill-advised decision.

It is important to realize that this capability for the unconscious brain to get out in front of the conscious mind makes us vulnerable. In this regard, there are at least two ways that we can be tricked into doing things we know we should not do. Most of us are familiar with the situation where we are driving along a familiar route and for some reason, need to deviate from our typical course. Perhaps, it is the route we take to work each morning, but it is the weekend and we are going somewhere else. As we drive along, we become distracted and suddenly realize we turned at the same place we would have if we were going to work taking us off our intended route. In this case, there was a well-learned behavior that happened to be inappropriate for the situation. Given that the conscious mind was distracted, the brain ignored the current intentions and went in the familiar direction. In general, wherever people are asked to deviate from well-learned routines, the conscious mind must watch to make sure the brain does not act out of habit. Unfortunately, our minds can be easily distracted.

Another way to take advantage of the brain getting ahead of the conscious mind involves situations that create a false sense of urgency or prompt a reflexive reaction. Internet scammers frequently employ this mechanism. One popular scam has a pop-up window appear that says that a scan of your computer has revealed critical vulnerabilities and offers a link to a report that tells you more. The goal is to trick the computer user into clicking the link which may take them to some type of ad or even download malicious software. Some have even elevated the warning to say that the scan has detected someone else is on your computer. In either case, the scammer seeks to appeal to fear causing the computer user to reflexively respond, before having actually thought through the situation or the potential consequences of their actions. Many find it surprising how often computer users will do things that cause their machines to become infected and spread viruses and other malicious software programs to other computers. However, the scammers and hackers are merely taking advantage of vulnerabilities we all share that emanate from the distinction between our unconscious brain, which sees and reacts, and our conscious mind, which contemplates the consequences of our actions, and the respective timeframes in which the unconscious brain and conscious mind operate.

Default network -- mind wandering

Whereas one key distinction is that between conscious and unconscious brain processes, a second key distinction exists between whether our conscious awareness is directed internally or externally. Whether daydreaming, fantasizing or replaying a story or event, the mind is prone to wander. This is true for all of us with some exhibiting an even greater propensity for mind wandering, with the effects of mind wandering revealed in lower levels of performance for both laboratory and everyday life activities (McVay, Kane & Kwapil, 2009). Neural imaging studies have identified a network of brain regions that tend to be active during periods in which conscious awareness is focused inward (Mason et al, 2007). This network has been referred to as the "default network" based on a belief that it represents a state of activation the brain naturally gravitates toward when not attending to external events. Mind wandering occurs effortlessly and often, one does not realize that their mind has wandered until long after they have ceased attending to surrounding activities. In fact, activity in the default network is most pronounced during episodes of mind wandering in which the person does not realize they have allowed their mind to wander (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009). Certain conditions and different individuals may be more or less susceptible to mind wandering, with there often being little, if any, indication that an individual is not paying attention.

More often than not, there is an implicit assumption within systems design that operators, users and other human components of the system are consciously aware of their surroundings. This is in contrast to an alternative perspective, and perhaps safer assumption, that at any given point in time, individuals are inattentive and have no conscious awareness of messages presented to them, activities occurring around them or impending events that may impact upon them. Within the context of everyday human interactions, there are various mechanisms that allow us to gauge the attentiveness of others and to intervene to assure untoward lapses in conscious awareness are avoided. We state that something is important, we asks for verification that we have been heard and we are attentive to behavior that is unexpected. Few technological systems behave similarly, while often relying on people to be attentive for their successful, and sometimes safe, operation. Furthermore, certain circumstances have the effect of making people more susceptible to mind wandering than they might be otherwise. The following sections summarize some common situations that make mind wandering more likely.

Verbal rehearsal

Verbal rehearsal, as well as other modes of mental rehearsal, represent a form of mind wandering in that there is little conscious awareness of external events as the mind constructs the right thing to say or imagines an upcoming performance. In general, where situations prompt preparatory activities, one will be prone to mind wandering. A common example occurs during meetings in which everyone is asked to go around and introduce themselves. Anyone who has been in this situation knows that it is often difficult to attend to those who go before you as you imagine what you are going to say.

Threats to self-esteem

When one is presented with threats to their self-esteem, there is a tendency to ruminate. Links have been demonstrated between conditions such as clinical depression and obsessive-compulsive disorder that involve debilitating rumination and heightened activation of the default network (Berman et al, 2011; Gentili et al, 2009). Whereas personal criticism may serve to get someone's attention, it can often have the opposite effect. This is particularly true when the recipient of a critical appraisal does not agree with the appraisal (Heradstveit & Bonham, 1996;

Roseman, Spindel & Jose, 1990). Any critical appraisal can cause an individual or group to become disengaged. Yet, an erroneous negative appraisal provokes negative emotions that provide a particularly strong catalyst for extended, inwardly focused ruminations.

Physical discomfort

It is difficult to sustain attention when one is physically uncomfortable. Unpleasant bodily sensations compete for one's conscious awareness. This is evident from studies showing that when experiencing discomfort (e.g. visual discomfort), subjects respond significantly more slowly in measures of sustained attention (Conlon & Humpheys, 2001). It can be quite demanding to try and ignore the sensation of physical discomfort with these demands draining the resources available to attend and respond to external events. Thinking about being hot or cold, how much one hurts or how bad one feels each involve a certain level of conscious disengagement.

Boredom

Perhaps, the condition we most commonly think of as being conducive to mind wandering is boredom. Boredom may be thought of as a state of underload during which the brain is inadequately engaged and it becomes exceedingly difficult to sustain attention to external stimuli. I like to say that the mind wants to be entertained and if not entertained, it will entertain itself. Boredom is most likely to arise when there is a lack of change or novelty, and events, activities and interactions become repetitious. The brain is unusually sensitive to predictable patterns. Given the complexities of life, this is highly adaptive because limited resources need to be devoted to situations where you know what is going to happen. Consequently, if you know what is going to happen, there is no need to be attentive and when situations are predictable, there is an opportunity to disengage and turn our conscious awareness inward.

Interestingly, it has been noted that doodling may offer a mechanism to effectively confront boredom and allow the brain to remain engaged in external activities. Andrade (2010) reported a study in which subjects were asked to listen to monotonous telephone conversations for the names of people coming to a party. Subjects were assigned to either a group that were provided paper and pen, and asked to doodle as they performed the task, or a group that was not allowed to doodle. It was found that the subjects who doodled performed significantly better monitoring the conversations for names and afterward, remembered more of the names than the group that was not allowed to doodle. This suggests that providing an activity that allows the mind to stay engaged in an externally focused activity may lessen the tendency to become absorbed in internal thoughts, enabling more attention to remain focused on external events.

Often, there is some degree of mental exertion required to sustain attention to external events, particularly when events are repetitive and have become boring. The level of default network activity covaries with the level of task engagement. When an individual is engaged in an external task, the transitions between the default network and its counterpart, a network of brain regions that are active when an individual is attending to and responsive to external stimuli, are relatively distinct. In contrast, when an individual is less engaged, the transitions in and out of the default network become somewhat indistinct, with there being greater variability in task performance (Kelly et al, 2008). In a recent study, subjects were shown commercially-produced films with it assumed that their appraisal of the films would be correlated with their tendency to mind wander. Thus, subjects who were not interested in the films and became bored were expected to exhibit more mind wandering. fMRI recordings provided an indication of the level of activity in the default network. Subjects who showed more transitions in and out of the default network, indicating a greater propensity for mind wandering, gave more negative appraisals of the films than subjects who exhibited fewer transitions. Furthermore, analysis of the activity within the brain regions making up the default network showed less covariance in subjects who exhibited more mind wandering and also gave films poorer ratings. These subjects not only mind wandered more, but their default network was more fully engaged. This suggests deeper levels of disengagement. Furthermore, as their minds wandered, there was greater covariance in activity of default network suggesting a fuller engagement of this network (Grubb et al, 2012)

In general, mind wandering corresponds to a state of reduced brain activity. This has been demonstrated by asking subjects to perform a simple, repetitive task for an extended period of time (Smallwood et al, 2008). Specifically, subjects were presented a series of X's, which served as non-targets, and their task was to respond when they were presented a target, which consisted on a number. About 10% of the stimuli were targets. Subjects quickly began to mind wander which was evident in their frequent failures to respond to targets and their responses to non-targets. Additionally, subjects were asked to report on their own mind wandering providing researchers with both performance data and self-reported mind wandering as bases for identifying periods of time in which subjects had become disengaged from the task. Within EEG recordings, there was a pattern of response (i.e. a visual evoked potential) that corresponded to stimulus presentation. During periods in which the subjects exhibited evidence of mind wandering, there was a lower amplitude EEG response indicating a relatively reduced baseline level of brain activity.

Inattentional blindness

Have you ever had the experience where you are looking for something that is right in front of you, but you do not see it until someone points it out to you? Following a collision, motorists often comment that they had looked, but never saw the other vehicle. Designers generally believe that if there is a highly salient signal, it is safe to assume that it will capture people's attention. However, just because the brain is receiving and processing sensory information, with there being activation of brain regions in response to the sensory stimulation, you cannot assume conscious awareness of the sensory information (Logothetis & Schall, 1989; Leopold & Logothetis, 1996).

The phenomenon known as "inattentional blindness" provides a particularly poignant demonstration that salient sensory stimulation may not be perceived at a conscious level, despite being readily available to the sensory system. Demonstrations of inattentional blindness generally involve a complex visual scene with subjects instructed to focus their attention on a specific facet of the visual scene. For instance, one demonstration presents two groups of people in different colored outfits with each group passing a ball back and forth at the same time (Simons & Chabris, 1999). The observer is instructed to count the number of times that one of the two groups passes the ball. It is a busy scene and one must pay close attention to keep track of the designated group. As the scene unfolds, a highly salient event will occur. For example, a person dressed in a gorilla costume will walk from one to the other side of the scene, stopping in the middle to dance or perform other moves. On first witnessing this demonstration, most observers do not report seeing the gorilla. Then, having had it pointed out to them that a person in a gorilla suit passed through the scene, they are astounded that they had not noticed something so obvious.

Attention seems to be the critical factor in determining the response of the brain to sensory stimuli, with stimuli that are the focus of attention triggering the expected brain response. In contrast, when equivalent stimuli are not the focus of attention, critical higher-level brain processes do not respond, as if the stimuli had never occurred. Rees et al (1999) demonstrated this effect in a study in which subjects were shown letter strings superimposed onto images. Subjects were instructed to attend to either the letter strings or the images. When attention was focused on letter strings and they contained meaningful words, as compared to random consonants, there was activation of brain areas that are generally active during language processing. In contrast, the same stimuli produced essentially no activation of these brain areas in conditions in which subjects were instructed to attend to the visual scene, ignoring the superimposed letters. It should be noted that unattended sensory information triggers activation of initial low-level sensory processes, indicating that the brain senses the stimuli, yet it is in the time period 200 msec or more after the stimulus when higher-level brain processes would normally be active that there is no response (Sergent, Baillet & Dehaene, 2005).

Inattentional blindness occurs when the sensory systems of the brain are presented competing demands. In these situations, the brain copes by not merely favoring one task over the other, but by actively suppressing activation associated with the competing task (Todd, Fougnie & Marois, 2005). The effect may be the product of demands to either focus on ongoing sensory events or to hold recent sensory experiences in short-term working memory. For example, either asking an individual to monitor a complex stream of sensory information or asking them to remember one or more complex sensory experiences is sufficient to consume the available resources forcing the brain to cope by ignoring other ongoing demands. Brain activity elicited by the competing sensory experiences is transmitted through the lower-level sensory circuits (e.g. areas within the visual or occipital cortex responsible for distinguishing shapes, colors and other physical attributes of a stimulus), but is suppressed as it reaches the higher-level brain processes that provide the basis for our conscious awareness of the sensory events. While the most pronounced demonstrations of inattentional blindness involve a single sensory modality, it can also occur in situations involving multiple sensory modalities (Sinnett, Costa & Soto-Faraco, 2006). For example, by focusing attention on visual information, an individual may fail to perceive auditory information, or vice versa. Yet, it should be noted that the same brain mechanisms that make us susceptible to inattentional blindness also allow us to listen to a single conversation while standing in a crowded room where several people are talking at the same time.

These facets of brain function have important ramifications for system design. In particular, where there is reliance on the human to sense and respond to environmental stimuli, it must be recognized that there is a limited capacity to simultaneously monitor multiple streams of sensory input, particularly when one of those streams is both demanding and the focus of attention. Furthermore, in high demand situations, the brain's mechanisms for coping operate automatically and at an unconscious level. Consequently, an individual may have no conscious awareness that they have actively ignored potentially significant facets of the overall sensory experience. It cannot be assumed that the individual has made a conscious decision to ignore some sensory input in favor of others. Instead, the brain operates outside of the individual's conscious awareness to actively suppress competing sensory experiences as a means to enable the individual to cope with the demands of the task on which they have focused their attention.

Implicit operations of the brain

It has been emphasized in previous sections that the majority of what the brain does occurs at an unconscious level. The following sections summarize several ways in which the unconscious operations of the brain are manifested within our daily activities.

Implicit memory

One of the most basic distinctions made regarding human memory concerns that between recall and recognition. Within naturalistic settings, an individual may be able to recall very little of what they have experienced. For example, taken on a tour through an unfamiliar city or building, immediately afterward, and even days or weeks later, one will only recall the most salient and meaningful sights. However, if shown a series of photographs and asked if they had or had not seen various sights, people will respond with accuracy far above chance for sights that they could not recall having seen. During the tour, the individual may have paid little attention to many of the sights, yet the visual images were processed at an unconscious level and memories formed that while they could not later be consciously recalled, were sufficient to produce a sense of familiarity. It should be noted that this effect does not contradict the previous discussion of inattentional blindness where there is no subsequent awareness of certain sensory experiences. Inattentional blindness occurs when attention is focused on one stream of sensory experience and the associated demands cause the brain to suppress input from competing streams of sensory experience. The phenomena being addressed here occurs when attention is focused on a given stream of sensory experience, yet some is processed at a conscious level, while the rest may be momentarily processed at a conscious level, but is processed primarily at an unconscious level.

The mechanism whereby we are capable of recognizing items from our past experience that we are unable to intentionally recall has been referred to as implicit memory and serves as the underpinnings for otherwise unaccountable feelings of familiarity with specific objects, people and places, as well as sensory experiences such as sounds, smells, etc. Within the brain, there are parallel processes that are activated by sensory experiences with one providing the basis for explicit memory and the other providing the basis for implicit memory. The distinction is apparent in cases where brain damage has left explicit memory intact with there being little of no accompanying implicit memory, or has left implicit memory intact, with there being little or no accompanying explicit memory (Gabrieli et al, 1995). There are three patterns of brain activity that occur when test subjects are shown a series of stimuli, and later shown a second series of stimuli and asked to indicate which items from the second series appeared in the first series (i.e. old) and which did not (i.e. new) (Rugg et al, 1998). One pattern appears with words correctly classified as having not appeared in the first list (i.e. new), a second for words that appeared in the first list and are correctly recognized and a third for words that appeared in the first list, but are not correctly recognized (i.e. false negatives). This latter pattern of neural activity where the brain seems to recognize the word at an unconscious level, yet the subject does not consciously recognize the word has been linked to the common experience of "familiarity." This is the experience where we see something that seems oddly relevant to our self and our past experiences, yet we do not immediately realize what connection may exist.

In the design of information displays, it is worth asking whether the objective is for information to be later recalled, or merely recognized. A comparison of the brain regions that are most active during recall and recognition reveals a greater engagement of executive functions during recall (Cabeza et al, 1997). In contrast, there is a greater engagement of brain regions associated with perceptual processes during recognition. Consequently, where the objective is for information to later be recalled (e.g. a code that must be read and later entered, or an instruction that is given at one time and must be executed at a later time), there is the need to present information in a way that will engage executive functions and facilitate those executive functions when the time comes to recall the information. For instance, this occurs when we prepare a hint or use some form of pneumonic device to help us later recall a password, procedure or other information. In other cases, the objective may be for information to later be recognized (e.g. recognizing the path through a building or menu system) or the objective may be for there to merely be a sense of familiarity (e.g. designers may want a new product design to evoke the positive sensations associated with a popular predecessor). In these situations, one might want to use perceptual features that will help bolster a sense of familiarity. This could occur through a variety of mechanisms such as the formatting of information, the background against which the information is presented or the context in which the information is presented, or the shape and feel of a product.

Behaviorally, implicit memory is often manifested through priming. Priming occurs when incidental exposure to a stimulus (e.g. a word) activates associated memories within the brain, yet this activation is slight and there may be no conscious awareness that the brain is responding to the stimuli (Schacter & Buckner, 1998). Experimentally, the effect of priming may be demonstrated through studies in which subjects exposed to words for durations so brief that there is not an opportunity to consciously process the word and its related meaning react faster when later asked to respond to semantically similar probes (Schacter, 1992). For example, if primed for an extremely brief exposure to the word “fire,” and later presented a series of words and asked to indicate which words describe a common injury, subjects will respond faster to “burn” than words not related to fire (e.g. sprain, burp). With implicit memory, there may be no conscious awareness of the stimuli that is the source of the memory. Yet, there is activation of brain processes associated with the stimuli and this activation prepares the individual to respond more readily or more robustly to the stimuli, or associated stimuli, at a later time.

In the design of systems, priming offers a mechanism to better prepare individuals to respond to upcoming events (Crundall & Underwood, 2001; Navarro, Mars & Hoc, 2007). This may occur through overt mechanisms such as instructions or videos that prepare an individual for an upcoming activity. For example, in many airports, prior to entering the security screening area, passengers are shown videos that depict the screening procedures. These videos serve as an overt prime reminding passengers of the rules and procedures and readying them to carry out these procedures more efficiently once they have reached the screening area. Priming may also be used in ways that are much more subtle. For example, with assembly operations, the parts and tools that will be needed may be laid out in the order that they will be used. Seeing the parts and tools associated with upcoming steps serves to prime memories for those steps allowing the operator to be better prepared when they reach those steps in the operation. Whether done overtly or through more subtle mechanisms, priming may be effectively used to elicit activation in neural circuits associated with knowledge or activities that will be required at a later point in time allowing the individual to respond more quickly and effectively when the time arrives.

Implicit learning

I like to say that, "learning is one of the things that brains just do." Learning is a byproduct of brain function and occurs whether or not there is a conscious intent to learn. As designers, we are constantly engineering experiences and when encountering those experiences, learning will occur. Of course this can be beneficial in many circumstances. However, one must be attentive to what might be learned, and specifically, what unintentional learning might occur.

Often, training involves the use of simulators that emulate the experiences of actual operational systems. Yet, for the sake of expediency, trainees may be allowed to skip over procedural steps that are essential with the operational system, but are unnecessary with the simulation-based trainer. Similarly, trainees may be required to perform a modified procedure to accommodate the peculiarities of the simulation-based trainer or the training protocol. In either case, trainees are acquiring patterns of behavior, as well as developing expectations regarding the behavior of the system and how the system will respond as they take various actions. This illustration highlights a rather obvious example. Incidental, unintended, or implicit, learning certainly may occur with salient tasks or facets of the environment. However, implicit learning may also occur for more subtle experiences, with much of what shapes implicit learning occurring outside of conscious awareness. Consequently, one is often unaware of what the brain is learning. As designers, we must attend to the subtle patterns, sequences and associations that are embedded within the experiences created by our products, and specifically, opportunities for potentially counterproductive implicit learning.

In engineering systems, whether or not it is done implicitly, there is an imposition of order where order might not have otherwise existed. Thus, within any engineered system, there is an inherent orderliness from which certain rules of operation may be extrapolated. Many years ago, I led a research team that undertook the job of developing a capability to use the data generated while operating an automobile (e.g. steering wheel rotation, lateral acceleration, etc.) to make real-time inferences concerning the ongoing driving context (e.g. approaching an intersection, executing a lane change, etc.) Initially, I had some concern that driving was such an open-ended task that we would have little success applying the machine learning techniques that had worked well within laboratory settings for relatively constrained activities. However, I was pleasantly surprised when our algorithms did quite well predicting a wide range of driving contexts (Dixon, Lippitt & Forsythe, 2005). In retrospect, I later realized that I had underestimated the extent to which driving is a highly constrained activity. The structure of the roadways imposes many constraints that limit the realm of possibilities. Furthermore, the rules of the road and the behavior of the other drivers impose further constraints. Finally, the automobile itself offers even more constraints. There is an implicit orderliness and corresponding rules associated with driving that through our experiences we have all learned. Yet, like me, unless we are given a reason to consciously think about these rules, they rarely enter our awareness, although they are constantly shaping our behavior and experiences. Implicit learning refers to the process whereby our brains unconsciously recognize patterns and infer the relevant rules that emanate from those patterns during our day-to-day experiences.

Experimentally, implicit learning has been examined in studies that present subjects with a series of meaningless stimuli that may or may not follow a consistent pattern. For example, subjects may be presented the letters, “A,” “B,” “C,” and “D,” with a different finger assigned to each letter and the instructions to press a key with the corresponding finger whenever a letter is presented (Eimer et al, 1996). When the letters are presented randomly, the reaction time associated with each letter is approximately the same. However, when the letters are presented in a sequence (e.g. A,C,D,B,A,C,D,B…), reaction times decrease over a series of trials, although often subjects cannot accurately report the sequence. The fact that the reaction times decreased implies that the subject had learned the sequence, although implicitly, at an unconscious level. When an individual prepares to execute a motor response, there is increased activation of brain regions on the side of the brain opposite the limb that will execute the response (i.e. lateralized motor potential). With implicit learning of sequences, this increased activation occurs prior to presentation of the stimulus implying that the individual anticipates the response that will be triggered by the next stimulus. Furthermore, once an individual has learned a sequence, if an unexpected stimulus (i.e. deviant) is inserted (e.g. instead of the A,C,D,B pattern, the series, A,B,D,B is presented), there is a wave of activity that spreads across the brain in response to the out-of-sequence stimuli. This occurs whether the subjects can or cannot consciously report the sequence, although there is a larger magnitude response to a deviant stimulus is if the subject is consciously aware of the sequence, as compared to subjects that are not consciously aware of the sequence.

With experimental paradigms such as the one described in the previous paragraph, if subjects are provided enough exposure to a recurrent sequence of stimuli, they will generally recognize the sequence and be able to accurately report it. Thus, learning progresses from an initial stage in which there is implicit knowledge of the sequence as evidenced by reduced reaction times to a later stage in which there is explicit knowledge as evidenced by the ability to correctly report the sequence. This transition is marked by an accompanying transition in the activation of neural circuits (Honda et al, 1998). During the implicit learning stage, decreases in reaction time are correlated with activation in the primary sensorimotor cortex. This activation may be interpreted as priming where expectations regarding the next stimulus-response pairing in the sequence leads to anticipatory activation of the corresponding neural circuits. In contrast, during the explicit learning stage, there is a correlation between the accuracy with which subjects report sequences and activation across a broad area that encompasses parietal cortex, precuneous and premotor cortex. This latter pattern of activation may be interpreted to indicate greater awareness of the stimulus-response sequence with increased conscious control of task performance.

Implicit perception

Much has been said about the potential influences of subliminal messages and their use within various contexts. Subliminal stimuli are perceptual cues that are either of too low of a magnitude or too short of a duration to be perceived at a conscious level (i.e. subthreshold), yet they may have a psychological or behavioral influence (Dehaene et al, 2006). It has been shown that presenting words with either a positive or negative connotation for as little as 1 millisecond is enough to produce a measurable response in the brain (Bernat, Bunce & Shevrin, 2001). Furthermore, unpleasant words produced a larger amplitude response and a somewhat different pattern of response than pleasant words. This illustrates that at an unconscious level, verbal stimuli for which one has only been exposed for an instant can evoke patterns of brain activity associated with either pleasant or unpleasant sensations. Whereas we generally think of subliminal stimuli as messages engineered to affect recipients in a certain way, we are constantly being bombarded by stimuli that our brains process at an unconscious level. Some of these may be subthreshold or subliminal, but most are of a magnitude and duration that they would be readily perceived if they were the object of our attention.

As designers, there is a tendency to only consider the facets of a design that are related to the functions of a product, environment or system. However, other incidental factors will create perceptual sensations that may not be consciously perceived, but influence how our design is experienced. It has been said that, “99% of design is invisible” (99% Invisible, 2012). This expression may be interpreted to convey the idea that when people interact with our designs, they may only be consciously aware of 1% of the overall design. However, their experience is shaped by the entirety of the design and the resulting sensations created by the design. This serves as a caution that otherwise good designs can go awry without sufficient attention to detail. For example, a restaurant may place trash at a location such that the patterns of air flow result in the dining area being permeated by imperceptible odors of food waste. Customers may not consciously recognize the odor, but find their dining experience inexplicably unpleasant. Likewise, subtle details of design may be used to create a positive impression. Automobile makers appreciate the effect of the sound a car door makes when it is closed and electronics makers understand that devices need to produce a solid snap when they are closed. Many years ago when commercial airlines regularly served meals on lengthy flights, a persistent meme revolved around the poor quality of the meals served on flights. When passengers were asked to rate various facets of their travel experience, it was found that a correlation existed between how well passengers rated the quality of the meals an airline served and the associated service, and how well they rated the safety of the airline (Rhoades & Waguespack, 1999). This is a particularly telling example because safety is an aspect of the airline that passengers have very little evidence to judge how well an airline is doing. Yet, passengers seem to have made the assumption that if the airline got the meals and meal service right, they were probably doing a good job with safety.

The phenomenon whereby a stimulus processed at an unconscious level has a measurable effect on behavior and psychological experience is known as *implicit perception*. It is often difficult to distinguish implicit perception from implicit memory given the mutual dependence of perceptual and memory processes within everyday activities. Perhaps, the clearest illustration of perception without conscious awareness occurs with motor behavior where perceptual processes construct an internal representation of the environment as a basis for guiding actions with respect to specific goals (Rossetti, 1998). While perception is essential to most motor actions, there is little conscious awareness of the corresponding perceptual experience. We carry out motor acts that are continuously mediated by perceptual knowledge and ongoing perceptual input, however we are rarely aware of the corresponding perceptual experiences.

An extreme example of implicit perception occurs with the phenomenon of *blindsight* (Milner & Goodale, 1995). Blindsight is observed in patients suffering damage to the primary visual processing regions of the brain. With these patients, they have no conscious awareness of some portion of their visual field. For example, they may have no conscious awareness of the right side of their overall visual field, with their awareness of the left side remaining intact. However, if shown a target in the portion of the visual field for which they have no conscious awareness and asked about its presence or absence, or approximate location, or asked to reach for the target, these patients perform far better than chance. This performance indicates that the brain remains capable of processing the sensory information, yet there is no conscious awareness. Blindsight has been attributed to the distinction between two separate visual pathways. The dorsal or *how* pathway processes information concerning how to act toward objects and the ventral or *what* pathway processes information about the identify and characteristics of the object (Milner & Goodale, 1995). In blindsight, the dorsal pathway remains intact allowing the individual to execute appropriate motor responses, while damage to the ventral pathway impairs their ability to consciously recognize the target.

In everyday activities, a wide array of brain processes is engaged in a seamless, somewhat symphonic, accord. The degree of conscious awareness devoted to an activity may vary, as well as what facets of the activity are the subject of our conscious awareness. Yet generally, for familiar activities, there is little conscious awareness of the countless brain processes that combine to enable us to perform the activity. The proficiency with which we perform these activities testifies to the depth and breadth of the brain's capacity to process perceptual information at an unconscious level. It is important to remember that this unconscious processing involves some level of appraisal of attributes such as pleasantness, unpleasantness, etc. Consequently, as designers, we must assume that every detail matters. Every detail will be sensed and appraised. No matter how removed a facet of our design may be from the direct operation of a device or system, if users have any exposure, whether direct or indirect, it will shape their experience of the product.

Automaticity

Within the course of everyday life, we engage in countless activities that involve a repetitive routine that does not change from one occurrence to the next. For instance, my morning routine on work days generally involves taking a shower, shaving, getting dressed, eating breakfast, brushing my teeth and finally, collecting the things I will need for the day, telling my wife goodbye and leaving the house. This routine has not only been learned, but the learning is so deeply engrained that much of the time, my mind is consumed with other thoughts, and I devote little attention to these activities. The level of automaticity becomes apparent when something causes me to deviate from the routine. In these cases, I am likely to forget a step in the sequence. For instance, on more than one occasion, I have gotten in the shower and found there was no soap. The mere variance of turning off the water to get a new bar of soap and starting over again, has been sufficient to cause me to forget to shampoo my shaved scalp. Similarly, my wife asking me to do something during breakfast has been enough to cause me to forget to finish my breakfast and leave the dirty dishes on the table, instead of my usual routine of taking them into the kitchen and rinsing them. Without any effort, our brain learns these repetitive sequences of behavior and is capable of carrying them out with little or no conscious thought.

When learning a new skill, there is a progression from the initial stages where there is the need for conscious attention to later stages in which the activity can be performed effortlessly with little or no conscious attention. With tasks that are primarily sensory-motor (e.g. manual tracking), the initial stages involve increased activation of cortical regions (frontal cortex, somatosensory cortex and parietal cortex) associated with executive functions, processing somatosensory feedback and motor planning (Floyer-Lea & Mathews, 2004). Once the task has been well-learned, activation shifts to subcortical regions (cerebellum and basal ganglia) associated with the coordination and execution of motor actions. Similarly, where learning involves a series of actions performed in a specific order, a shift in activation from regions associated with conscious control of actions to regions involved in execution of learned sequences of actions (supplementary motor area, and putamen and globus pallidus of the basal ganglia) occurs (Poldrack et al, 2005). Within the subcortical regions of the brain (i.e. basal ganglia and associated areas), there are specialized circuits that enable well-learned actions to be carried out with little or no conscious awareness. This automaticity allows conscious attention to be focused on other facets of the environment, or as often occurs, turned inward. Automaticity also serves as an essential interim step in constructing sequences of complex actions. In this case, initially, each action may require significant attention during learning, but once learned, may be treated as a chunk and combined in a sequence with other similarly complex actions. This occurs with combinations of chords in music, in sports activities such as the combinations of step sequences, postures, attacks and defenses in martial arts, and with professional activities that involve sequential series of actions (e.g. detailed assembly operations).

While the brain processes underlying automaticity have been most extensively studied for sensory-motor activities, the potential for automaticity extends to a broad range of cognitive activities. For instance, proficiency in reading (Wolf, Bally & Morris, 1986), speech comprehension (Friederici, Meyer & Cramon, 2000) and mathematics (Dahaene & Rokny, 1995) have each been linked to automaticity of basic operations within the brain. Furthermore, these processes similarly underlie the formation of many habits and ritualistic behaviors (Graybiel, 2008). From a systems design perspective, one might consider the overall array of behaviors that might occur in achieving various objectives and ask, “what is the potential impact of automaticity?” In many cases, automaticity may allow increased efficiency and allow individuals to focus their attention on other more important events. In this case, a designer may look for opportunities to create repetitive activities, as well as opportunities to combine repetitive sequences into longer series of actions. However, automaticity can also prompt some degree, and sometimes complete, conscious disengagement. Thus, where the potential for disengagement imposes risks, designers should be sensitive to this potential and introduce design features that intentionally engage conscious processes (e.g. system probes that require non-standard responses). When implemented effectively, the operator may continue to experience the benefits of automaticity, but is occasionally reminded to think about what they are doing so that they do not become completely disengaged from the ongoing acitvties.

Unconscious cognition

When presented a challenging problem, there may be a period in which we are consciously focused on solving the problem. Yet, when our attention is directed elsewhere and we are no longer consciously focused on the problem, does our brain continue to work on it? It has been asserted that the ah-ha phenomenon, where the solution to a problem occurs to us spontaneously at a time when we may not actually be thinking about the problem, suggests that the brain has continued to work on the problem, but at an unconscious level (Metcalfe & Wiebe, 1987). Jung-Beeman and colleagues used a common paradigm for studying creativity, defined as the solution of problems through insight, as opposed to analytic strategies, that is known as the remote associates test. In this test, subjects are presented three problem words (e.g. pine, crab and sauce). Their task was to identify a word or phrase that connects the three problem words. In this example, the correct answer would be, “apple.” In this study, subjects were asked to respond with a button press when they had attained a solution and then report their solution. After each trial, subjects were asked to indicate whether or not the solution involved insight (i.e. came to them suddenly). fMRI recordings found that the feature that most clearly distinguished trials in which subjects reported an ah-ha experience was an increased level of activity in the right hemisphere of the brain (i.e. right anterior superior temporal gyrus). Using the same procedure, a second experiment showed that in the time period immediately prior to their response on trials involving insight, subjects exhibited a burst of high frequency brain activity in approximately the same area of the right hemisphere.

Interestingly, it was also noted in the study by Jung-Beeman that prior to the burst of high frequency activity that corresponded with the ah-ha experience, there was a period of elevated slower frequency, or alpha activity. In this context, alpha activity was interpreted to reflect the suppression of neural processes. It was suggested that a suppression of interference from competing attentional processes may be essential for the right hemisphere to make distant semantic connections. Thus, the mechanisms underlying the ah-ha experience are suggested to involve a period during which there is activation of diverse semantic connections that occurs at an unconscious level. This may occur in parallel with more analytic processes involving the left hemisphere of the brain, which is normally associated with language-related processes, with these analytic processes dominating one's conscious awareness. It may be essential that the broad activation of semantic connections within the right hemisphere giving rise to a problem solution be accompanied by a momentary suppression of competing activation which serves to amplify the potential solution. This is then followed by a burst of high frequency activity which accompanies the emergence into conscious awareness of the solution, and the corresponding ah-ha experience.

It appears that in problem solving, the brain is capable of carrying out somewhat separate processes at both a conscious and unconscious level, and often, the solution arises as a product of its unconscious problem solving. However, to realize the benefits of unconscious problem solving, an individual must be capable of relinquishing their focused attention onto the problem long enough for a solution attained through unconscious processes to emerge into their conscious awareness. This suggests that certain environments may be more conducive to creative problem solving than others. In particular, an environment rich in engaging external stimulation will make it difficult to turn one's conscious awareness inward long enough to allow a solution to arise from their unconscious processes. Likewise, an environment that serves to keep an individual engaged in analytic problem solving strategies will similarly dampen their awareness of ongoing unconscious problem solving processes. In contrast, an environment that makes it easy to momentarily disengage from the immediate problem should have the effect of interrupting ongoing conscious problem solving strategies long enough for solutions to pop into one's conscious awareness from their unconscious brain processes. One can only wonder how many ingenious ideas have been lost due to single-minded dedication to an analytic problem solving strategy or the constraints imposed by organizational or other contexts to rely solely upon or to operate within an environment that favors certain problem solving processes.

What is the downside of unconscious brain processes?

On the surface, it seems great that the brain is continually working and we do not need to be consciously engaged, yet benefit from the products of our ongoing unconscious brain processes. However, while we can usually report our conscious thought processes with some accuracy, what we have learned or experienced implicitly is often inaccessible. Consequently, where there is a reliance on implicit learning, one often has a poor sense of what they have learned and how well they have learned it. Likewise, you do not know when you have forgotten something that you may have once learned. When asked to explain how you do something, your report will orient around those facets for which you have conscious awareness. Knowledge and skills that are the product of implicit knowledge will be reported unreliably and if pressed for an answer, as often occurs with expert accounts, one can only make their best guess as to exactly what they are doing and why they do it that way. In general, while unconscious brain processes may significantly impact the things we do and how well we do them, we have very little conscious access to those brain processes, or the associated knowledge.

Unconscious impact of cognitive state on decisions

Recently, Jonathan Levav and colleagues reported a research study that illustrates the extent to which unconscious brain processes shape conscious decisions, and particularly, may bias our decisions in ways that we do not appreciate (Danziger, Levav, Avnaim-Pesso, 2011). In this study, they looked at the parole decisions of judges in Israeli courts. These decisions involved a prisoner going before a judge and an argument being made for the judge to reduce their prison sentence due to their good behavior or other mitigating circumstances. Data was analyzed for a 10 month period and consisted of 1,112 hearings, with prisoners from four different prisons and decisions made by eight different judges.

The researchers considered whether parole was granted (i.e. the prisoner received a reduced sentence) relative to where a hearing occurred within the overall order of hearings on a given day. It was striking how the probability of being awarded parole varied over the course of a day. On any given day, there were three sessions. At the beginning of any one of these three sessions, the likelihood of a prisoner receiving parole was approximately 65%. However, by the end of a session, that likelihood had dropped to nearly zero. It did not matter how severe of a crime was committed, the amount of time that the prisoner had already served, whether the prisoner had previously been incarcerated, whether rehabilitation services were available, or the nationality or gender of the prisoner. The likelihood of being awarded parole was driven primarily by placement within the order of hearings within a given session.

The researchers attributed these results to the unconscious effects of fatigue on the cognitive processes of the judges. Specifically, it was asserted that as one becomes increasingly fatigued, they tend to choose the easier option and in this case, awarding parole was the more difficult decision because it involved incurring the risk that the prisoner would again commit a criminal offence. In contrast, it was an easy decision to deny parole because the prisoner returned to prison and there was no risk to society of their continuing to commit crimes. The key point is that the judges' decisions were systematically biased and they had no conscious awareness of this bias. At a conscious level, one may believe that they are operating in a consistent, unbiased manner, however any number of biases operating at an unconscious level to shape our conscious deliberations may be in effect, and we may never know how strongly we have been influenced by these unconscious brain processes.

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