Wisconsin Public Psychiatry Network Teleconference (WPPNT)

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Updates in Brain Science.

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“Science erases what was previously true.”

John McPhee
Agenda

• The Brain and the World
• Neuroanatomy, Briefly
• Sleep
• Consciousness
• Emotions
The Brain and the World

• The brain is the most complex structure we know of in the universe.

• The brain takes various inputs – some we call sight, some skin sensation, some sound, some smell, some taste – and creates an “internal model” of the outside world.

• Making this model is a creative act of the brain. The brain does not just “take a picture” of the world.
How Do We Know the Brain Creates Our World?

1) Science tells us that there are no colors, sounds, tastes, or even solid objects in the world. These are “perceptions” that come from our neurons being triggered by various chemicals, photons, electrical interactions, or compression waves. We perceive a color because of neurons that have responded to a certain wavelength of light. The brain then makes distinctions. There are many more wavelengths of light that we don’t see than we do see.
How Do We Know the Brain Creates Our World?

• 2) Studies in the visual sciences show that our visual acuity is “accurate” only for a very small part of our visual field (The fovea: thumbnail at arm’s length.) The rest is “constructed” by the visual system based on probabilities. We don’t notice our blind spot, our noses, or the blood vessels in the back of the eye, or our visual saccades (rapid, jerky eye movements, triggered by neuronal bursts up to 500/sec). In other words, we actually see very little of what we think we see.
The Visual System

• Our eyes are not simply cameras that take a picture of the world. There are only 150 million photo receptors in each eye, but there are billions of neurons in our visual cortex (the largest specialized area of the brain – 30%). These neurons turn the world into 3-D, and make allow us to see motion and shadows.

• The brain determines what we see, not the eye.
How Do We Know the Brain Creates Our World?

• 3) Our brain forces us to think in stories about what we see and what happens around us, rather than to gather data.
Origins

• Human beings have the longest period of dependence of any of Earth’s primates.
• One reason is so that our brain has time to be modeled for whatever environment we are living in. Although we have as many neurons as we will have throughout our lives, very few skills are “pre-wired” into us. This is very different than any other animal.
Maturing

• Ages to walking or swimming:
  • Dolphins: immediately
  • Horses: 45 minutes
  • Giraffes: 1 hour
  • Dogs: 14 days
  • Humans: 8-12 months
Important Early Experiences

• Physical and emotional exposure to other humans. Our neurons need contact with other neurons throughout our lives to develop and stay healthy.
• Exposure to a human language
• Exposure to the world – being able to see and manipulate objects
The Epigenome

• Exposure to various experiences is an important part of the epigenome that turns certain genes on and off, and modifies the structure of the brain.
Later Life

• The brain continues to change and grow throughout our lives. This is what is meant by saying the brain is “plastic.” It is malleable. New skills are learned. When the brain is damaged, new areas take over new functions. Cognitive reserve helps us delay the onset of dementia or other cognitive declines.
The Bottom Line

• The brain is a 5 pound mass of biological tissue, operating inside a closed, dark space, that takes electrical and chemical signals from outside of us and associates them together to create an internal model of the world.

• This internal model is not a picture of the world, but an approximation of the world.
The Bottom Line

Millions of years of evolution have allowed our genes to pre-wire certain circuits to make it more likely we will survive: desire to eat, aversion to harm, caring for young, instinct for bonding, sensitivity to language, etc. But in humans, instincts share influence with the ability to learn new behaviors. Hence our long period of dependency.
The Bottom Line

- The brain never quits growing and changing in response to experience.
Philosophical Implications

• The brain evolved to help us survive. Did it also evolve to reflect the outside world accurately? Our intuitions tell us we see the world as it is, but there is evidence that we are wrong. Science says the world is much different than our perceptions.

• It is probable that the world we know has only a passing resemblance to the “actual” world.
A Question

• Is the brain limited by its natural biological inputs? Or is the brain more like a processor that does not know or care where the inputs come from?

• It appears more and more likely the answer to this question is the latter. If that is the case, then we should be able to use the brain to incorporate an endless number of new data streams.
Brain Anatomy

• The human brain weighs about 3 pounds and uses 20% of the energy of our body (but very efficiently – about 11 watts.) It never rests. The “sleeping” brain is as active as the conscious brain. We just don’t know what its doing.

• The human brain is over 3x as large as a typical mammal with an equivalent body size. Most of the difference is the cerebral cortex, a layer of nerve cells over the cerebrum. Especially expanded are the frontal lobes. The portion devoted to vision is also expanded.
Brain Anatomy

• The brain is protected by the thick bones of the skull, a thick membrane (meninges), cerebrospinal fluid, and isolated from the bloodstream by the blood-brain barrier.

• The consistency of the brain is similar to soft gelatin.

• The brain is estimated to contain 80-90,000,000,000 glial cells and 80-90,000,000,000 neurons. There are 1,000,000,000,000,000 synaptic connections. The purpose of these cells is communication.
The Connectome

• The “connectome” refers to a “wiring diagram” of the brain – a mapping of all the neural connections.
• The idea is that the crucial functions of the brain are the result of neuronal networks.
• The Human Connectome Project is a 5 year NIH project, spread among two consortiums of research institutions.
• (Google the Human Connectome Project for more information.)
The Connectome

• The purpose of studying the connectome is to try to construct the brain by studying how all these cells are connected. Then we could reverse engineer the brain to better understand how it works (and what goes wrong.)

• We also might be able to work forward, and create a new brain, not limited by our biology...
Seeing Patterns is the Default Mode

- We cannot stop ourselves from seeing patterns in the world. “Split brain” experiments and other tests have shown that we normally create a story for everything that happens, often unconsciously.

- We want to believe the world is less random than it is. Which sentence do you prefer?:
  - The king died and then the queen died.
  - The king died and then the queen died of grief.
Dopamine

• High levels of dopamine appear to lower skepticism and make people more vulnerable to pattern detection. Treatment of Parkinson’s Disease with L-dopa, for instance, can lead patients to be more superstitious, more interested in astrology and gambling, etc.

• Dopamine dysfunction is also linked to paranoia – seeing patterns in events when other people do not.
The Narrative

• As mental health professionals, we should be aware of the nature of the human brain to be drawn to the simplest, most compelling narrative and understand that the story is not necessarily the truth.
Amygdala

• The amygdala receives input from the thalamus about body states (stress, alarm) and responds to emotional input and memories. It mediates arousal, directs motivation.

• It enhances learning and memory for emotional events. This includes recognizing when others are afraid.

• The amygdala processes most emotional information in teens. (Adults rely more on the prefrontal cortex to understand and evaluate fear.)
Amygdala

• The amygdala is best known for fear responses, but it also responds to positive stimuli. It is an important component of directing attention to emotionally salient events. Its neurons respond to sight, sound and touch.

• Damage here reduces signs of anxiety and impairs decision making. (Animals won’t learn to avoid foods that make them sick.)
Amygdala and Callousness

• Individuals with high callous and unemotional traits generally show reduced amygdala activation. Amygdala hypo-responsivity may correspond to callousness, and may be a hallmark of the psychopath. A hypo-responsive amygdala creates difficulty in recognizing fear shown by others.
Cerebral Cortex

• The cerebral cortex contains about 70% of the brain’s nerve cells, although it is only a quarter inch thick. The high concentration of nerve cell bodies gives the cortex a darker color than the rest of the brain –“gray matter.”

• Underneath the cortex, the brain is full of connecting fibers of neurons (axons) that are largely covered in myelin (fat insulation) – “white matter.”
Anterior Cingulate

• The anterior cingulate is a neural alarm system that signals when something is wrong or when an autonomic process should get conscious attention. It is particularly active during physical and social pain, probably carrying the emotional component. It also fires when others experience pain (empathy), working in tandem with the insula. Hyper-responsiveness here is a marker for developing PTSD.

• It monitors for conflicts and errors. It helps us distinguish between conflicting perceptions: “My parents loved me.” “My parents hurt me.”
Anterior Cingulate

- The anterior cingulate is actively involved in problem solving and moral dilemmas, integrating with emotional and sensory data, with strong connections to the dorsolateral prefrontal cortex.
- The anterior cingulate is also involved with behavioral motivation. Dysfunction results in amotivation and apathy.
The Ventral Cingulate

• The ventral cingulate appears to regulate emotional conflict by damping the amygdala. Disorders in these circuits are found in both anxiety and depression.
Awareness

• When we wake up every morning, we remember who we are. The ”I” disappears in deep sleep. Our EEG becomes very synchronized. Localized neuron stimulation (from TMS) does not spread across the brain as it does when we are awake.

• Consciousness arises in the interaction of neurons, not in the neurons themselves.
Sleep

• Sleep is complicated! We know that there are two forms of sleep: Rapid Eye Movement (REM) and Deep Sleep. Every cell in our body is affected by the light and dark. At least three dozen cell structures in the brain control sleep activity, located in the brain stem, the hypothalamus, and the basal forebrain.
How Does Your Brain Know It’s Time to Sleep?

• Socialization decreases
• Exercise decreases
• Light decreases
• You have eaten and have stopped eating
Sleep

• A complex system of neurotransmitters (acetylcholine, noradrenaline, GABA, histamine, serotonin, and orexin) are involved in two opposing circuits that inhibit each other – we are awake or asleep.

• During sleep, memories are revised and stored, waste products are removed from the brain, muscles are repaired, hormones regulated, etc.
“The rear light of consciousness, like the last express train of the night, began to fade into the distance, gradually speeding up, growing smaller than it was, finally, sucked into the depth of the night, where it disappeared. All that remained was the sound of wind slipping through a stand of white birch trees.”
The Unconscious

• The brain is always at work. Unconscious operations take place in the brain automatically. The “at rest” brain uses comparable levels of energy as the “awake” brain.

• The unconscious brain is constantly monitoring our internal milieu. We can instantly answer questions like “Are you hungry?” or “Are you worried?” without thinking about it.

• Unconscious circuits tend to drive responses very quickly. Conscious responses are slower. We can process the unconscious and conscious simultaneously (talk and drive a car).
The Unconscious

- The unconscious can cause the release of modulatory neurotransmitters, such as dopamine, norepinephrine, serotonin that effect neuroprocessing and increase the probability of certain types of behavior. For example, serotonin can modulate sociability and impulsivity, dopamine can modulate attention and desire, etc.
The Unconscious

- The unconscious handles a variety of important tasks that are best accomplished automatically, with great speed, and no room for choice. These include maintenance of fluid balance and composition, temperature regulation, control of blood pressure and oxygenation, swallowing, coughing, avoidance of danger, aggression, etc.

- Unconscious processing generally proceeds to output level before conscious actions. For this reason, we usually develop a “feeling” about events or people before we finish thinking about them.
Some Unconscious Processes

• Facial expressions are unconsciously modulated.
• Fear reactions are unconsciously modulated.
• The automatic coordination of eye movements, head position, muscle tone, and posture
• Learning new behaviors is conscious. These behaviors can then be taken over by the unconscious (riding a bike.)
Decision Making

• Cognitive psychologists believe that almost all, if not all, decisions that we make are first made in the unconscious, then transmitted to the cortex.

• This does not mean that “you” do not make your decisions. It means that the “you” that makes decisions is not the “you” that you are consciously aware of.
What is Consciousness?

• The mechanism that generates the feeling of being inside one’s body, making decisions and initiating actions is not understood.

• A benefit of consciousness is that it increases the number of variables that can be considered before implementing an action. New behaviors can be learned. Instincts can be resisted. We can retrain our unconscious in many cases (learning to like coffee...
Conscious Decision-Making

• When we delay making a choice, it allows us to weigh more options and allow more time for valuing, anticipating, getting more data. The extra time allows our consciousness to observe these thoughts. It is still likely that the feeling of “I’m a person making a decision” is a bit misleading. You are a unique person and “a decision is happening” is probably more accurate.
Emotions

• Emotions allow the unconscious to rapidly integrate with the conscious. (Emotions are not useful in an organism without consciousness. Organisms without consciousness act totally on instinct.)

• We sense our emotions from our body. After an argument, if your heart is still racing, you still feel angry. People who are paralyzed often complain that their emotions feel blunted. Taking a beta blocker which reduces heart rate and blood pressure helps you feel calm.
Emotions

• Emotions, unlike moods, occur in response to what is happening in the world and keep our brains focused on critical information. They motivate us to get what we want and avoid danger. They put a value on pieces of data.

• People with damage to emotional processing circuits remain very reasonable and able to understand events in the world, but cannot reason their way through complicated problems, including ethics. They are unable to make even simple decisions about what to wear, or whom to associated with. They fail at simple computer card games.
Basic Emotions

• Happiness
• Fear
• Sadness
• Disgust
• Anger
Social Emotions

• Guilt
• Shame
• Embarrassment
• Jealousy
• Pride
Emotions

• Emotions can be managed by distraction or reappraisal.

• Reappraisal is the process of reconsidering the meaning of an event. Reappraisal relies on the cingulate cortex and prefrontal cortex (similar to the location of the placebo effect.)

• Reappraisal improves with age.
Awareness of Emotion

• Pure focus on an individual’s emotional state reduces activity in the amygdala and increases activity in the prefrontal cortex. This may be the mechanism of mindfulness meditation and its ability to calm a person’s mental state (rather than simply doing relaxation exercises.)