The Neurobiology of Attention

by

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Disclosures

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Objectives

• Define attention and discuss the neurobiological basis of attention.
• Discuss the functions and development of attention.
• Discuss some impairments of attention.
What is Attention

Oxford Dictionary

• Notice taken of someone or something; the regarding of someone or something as interesting or important.
What is Attention

It [attention] is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others...

William James, The Principles of Psychology, 1890
What is Attention

- **Attention** is the behavioral and cognitive process that, at a particular moment, selectively enhances a discrete aspect of information, whether external (sound, image, smell...) or internal (thoughts), while inhibiting other perceivable information.
What is Attention

At the neuron level:
Attention is synchronized firing of a group of neurons whose rhythmic electrical activity exceeds the background chatter of neurons.

Desimone and Baldauf, 2014
Attention

• Modality specific (visual, auditory…)
• Spatial
• Temporal
• Cross modal
• Internal (thoughts, ideas, emotions)

Involuntary (automatic)
Voluntary (executive)
Attention in the Brain

- Ascending reticular activating system (brainstem, hypothalamus, thalamus)
- Cingulate cortex and insula
- Parietal cortex
- Limbic regions
- Frontal lobes (esp. prefrontal cortex)
- Modality-specific apparatus and regions
- Neurotransmitters: acetylcholine (Ach) (striatum/basal forebrain), dopamine (DA) (substantia nigra), and norepinephrine (NE) (locus ceruleus)
- Receptors: Ach - nicotinic, DA - D1 and D4, NE - alpha 2A adrenergic
The Balancing Act of Attention

- **Bottom-up:** external – size, intensity, repetition, novelty, duration, movement, contrast, change
- **Top-down:** internal – interest, desire, motivation, goal, past experience, aptitude, attitude, emotion, temperament
Model of Attention

- Alerting/vigilance
- Orienting
- Decision-making

Michael Posner, 1990
Model of Attention

Figure 2
Why do we need Attention?

• We are constantly bombarded by overwhelming amounts of perceptual information from multiple sources.

• Our brains constantly and rapidly try to make sense of the world so we can make appropriate behavioral responses.
Why do we need Attention

• Processing limitations
  - Finite processing resources at given time

• Response limitations
  - Can only move in one direction
  - Can only say one word at a time
  - Can only hold finite # of things
Functions of Attention

- Focusing
- Perceptual Enhancement
- Binding
- Action Selection - what you will do
- Sustaining Behavior - complete task
Limits of Attention

• Spatial – change blindness, inattention blindness

• Temporal – attentional blink, repetition blindness
Distraction

Interference in attention:

• Sources:
  
  External: noise, music, movement, activity
  Internal: emotion, boredom, fatigue, apathy

• Forms of distraction:
  
  Continuous distraction - accommodate
  Discontinuous distraction - disruptive
Types of Attention

• Involuntary/automatic/posterior
  alerting, orienting, habit/reward

• Voluntary/executive/anterior
  1. Focused
     Selective: select one focus out of many
     Sustained: maintain response for a time
  2. Divided
     Alternating: switch between tasks
     Divided: multi-tasking?
Development of Attention

(apparatus, processing speed, working memory)

- Infancy - alerting, orienting
- Childhood – executive (focused)
- Adolescence – executive (divided)
Impairments of Attention

- Confusional states - deliriums
- Hemi-neglect
- Anxiety
- Autistic disorders
ADHD

• Term used by the American Psychiatric Association, with or without hyperactivity.

• A neurological condition, usually genetically transmitted, characterized by distractibility, impulsivity and hyperactivity. Symptoms are present from childhood and with a much greater intensity than typical, and interfere with everyday functioning.
DSM-5 Criteria for ADHD

People with ADHD show a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development:

1. **Inattention**: Six or more symptoms of inattention for children up to age 16, or five or more for adolescents 17 and older and adults; symptoms of inattention have been present for at least 6 months, and they are inappropriate for developmental level:
   ◦ Often fails to give close attention to details or makes careless mistakes in schoolwork, at work, or with other activities.
   ◦ Often has trouble holding attention on tasks or play activities.
   ◦ Often does not seem to listen when spoken to directly.
   ◦ Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (e.g., loses focus, side-tracked).
   ◦ Often has trouble organizing tasks and activities.
   ◦ Often avoids, dislikes, or is reluctant to do tasks that require mental effort over a long period of time (such as schoolwork or homework).
   ◦ Often loses things necessary for tasks and activities (e.g. school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones).
   ◦ Is often easily distracted
   ◦ Is often forgetful in daily activities.
DSM-5 Criteria for ADHD

2. **Hyperactivity and Impulsivity:** Six or more symptoms of hyperactivity-impulsivity for children up to age 16, or five or more for adolescents 17 and older and adults; symptoms of hyperactivity-impulsivity have been present for at least 6 months to an extent that is disruptive and inappropriate for the person’s developmental level:

- Often fidgets with or taps hands or feet, or squirms in seat.
- Often leaves seat in situations when remaining seated is expected.
- Often runs about or climbs in situations where it is not appropriate (adolescents or adults may be limited to feeling restless).
- Often unable to play or take part in leisure activities quietly.
- Often "on the go" acting as if "driven by a motor".
- Often talks excessively.
- Often blurts out an answer before a question has been completed.
- Often has trouble waiting his/her turn.
- Often interrupts or intrudes on others (e.g., butts into conversations or games)

**In addition, the following conditions must be met:**

- Several inattentive or hyperactive-impulsive symptoms were present before age 12 years.
- Several symptoms are present in two or more setting, (e.g., at home, school or work; with friends or relatives; in other activities).
- There is clear evidence that the symptoms interfere with, or reduce the quality of, social, school, or work functioning.
- The symptoms do not happen only during the course of schizophrenia or another psychotic disorder. The symptoms are not better explained by another mental disorder (e.g. Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder).
Brain regions implicated in pathophysiology of ADHD
Neuroanatomical correlates of ADHD

- Cerebral volume – gray and white matter
- Prefrontal cortex
- Temporal lobe
- Parietal lobe
- Thalamus
- Basal ganglia (caudate and globus pallidus)
- Cerebellum
- Superior colliculus
Basis for ADHD

- Structural (MRI, DTI)
- Functional (fMRI, PET)
- Physiological (EEG)
- Chemical (DA, NE; ?glu, etc)
- Genetic (multiple – D1, D4, alpha 2A, DA beta hydroxylase, DA transporter)
- Environmental (prenatal and postnatal)
Attention

• Cognitive process by which certain information is selected for processing while other information is discarded.
• Based on synchronized neuronal activity.
• Uses a distributed network of brain areas.
• Develops in an organized way over time.
• Amount or allocation may be impaired.
Roles of Attention

• Making sense of the world
• Social/emotional connection
• Searching and locating
• Decision making
• Problem solving
• Trouble shooting
• Reasoning
• Planning
• Learning
• Memory