The Impact of Domestic Violence on Children’s Brain Development

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Objectives

• Define the types of abuse
• Review background information on the effects of abuse, including domestic violence, to better understand short- and long-term consequences
• Describe the different brain regions that are directly, and indirectly, impacted by domestic violence
• Discuss how this knowledge can shape diagnostic and treatment recommendations
The challenges

Can’t pay attention

boring
Definitions
Definitions

• Child Maltreatment
  – Physical abuse
  – Physical neglect
  – Emotional abuse
  – Emotional neglect
  – Sexual abuse

2. Egeland, B. Taking stock: Childhood emotional maltreatment and developmental psychopathology
Neglect and Abuse

• **Neglect**: parent/guardian has
  – Harmed the child
  – Failed to properly care for the child by providing inadequate education or medical care
  – Abandoned the child

• **Abuse**: parent/guardian injured the child
  – Physically
  – Sexually
  – Mentally
  – Emotionally
Background
(Not at all) Fun Facts about Abuse

• Annually
  – 702,000 children in US maltreated in 2009 (reported)\(^1\)
  – ~900,000 child victims of abuse/neglect (12/1,000 children)\(^2\)

• CPS evaluations\(^2\): 30% substantiated → youngest children at highest risk
  – 60% neglect (2% medical neglect)
  – 16% physical
  – 8% psychological\(^3\)

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2. Hayes, JP. Parenting Assessment in Abuse, Neglect and Permanent Wardship Cases.
(Not at all) Fun Facts about Abuse

• Costs: lifetime exceed $210,000 per victim (law enforcement, child welfare, medical treatment/hospitalizations, loss of productivity)
  – Helps justify why financially you would want to prevent/fund prevention programs
    • Such as The Nurse Family Partnership, Positive Parenting Program (Triple P)

Klika, JB & Herrenkohl, TI. A review of developmental research on resilience in maltreated children.
Background

• Children’s brains primed to learn new experiences, but also makes them more susceptible to environmental stresses

Odgers, CL & Jaffee, SR. Routine versus catastrophic influences on the developing child.
Biological

- Early Years Study 2: poor caregiver-infant interactions compromised formation of neural circuits and pathways\(^1\)
- Cortisol and catecholamines: \(^\uparrow\) with stress from abuse \(\rightarrow\) destruction of brain cells, disrupts neuronal connections\(^2\)

1. McCain NM, Mustard F, & Shanker S. Early Years Study 2. Putting science into action.
Background

• Clear dose–response relationship between severity of exposure and magnitude of the neurobiological findings

2. Dannlowski, U et al. Limbic scars: Long-term consequences of childhood maltreatment revealed by functional and structural magnetic resonance imaging.
3. Edmiston, EE et al. Corticostriatal-limbic gray matter morphology in adolescents with self-reported exposure to childhood maltreatment.
4. Teicher, MH, Anderson, CM, & Polcari, A. Childhood maltreatment is associated with reduced volume in the hippocampal subfields CA3, dentate gyrus, and subiculum.
5. Treadway, MT et al. Early adverse events, HPA activity and rostral anterior cingulate volume in MDD.
Background

• Survivors of childhood maltreatment have a higher prevalence of mental health/cognitive effects:\(^1-^7\)
  – Depression
  – Anxiety
  – Substance abuse
  – Eating disorders
  – Suicidal symptomatology
  – Psychosis
  – Personality disorder
  – Diminished cognitive functioning
  – Poorer treatment response

• Maltreatment accounted for **45%** of the population attributable risk for childhood onset psychiatric disorders\(^8\)

1. Ball, JS & Links, PS. Borderline personality disorder and childhood trauma: Evidence for a causal relationship.
2. de Bellis, MD et al. Neuropsychological findings in childhood neglect and their relationships to pediatric PTSD.
5. Nanni, V, Uher, R & Danese, A. Childhood maltreatment predicts unfavorable course of illness and treatment outcome in depression: A meta-analysis.
7. Teicher, MH & Samson, JA. Childhood maltreatment and psychopathology: A case for ecophenotypic variants as clinically and neurobiologically distinct subtypes.
Background

- Survivors of childhood maltreatment have increased prevalence of physical health disorders:
  - Inflammation\(^1\)
  - Metabolic syndrome\(^2\)
  - Arthritis\(^3\)
  - Ischemic heart disease\(^4\)
  - Cancer\(^5\)
  - Shortened telomeres associated with reduced life expectancy\(^6,7\)

2. Danese, A et al. Adverse childhood experiences and adult risk factors for age-related disease: Depression, inflammation, and clustering of metabolic risk markers.
The Brain
Background

• Clearly able to show: link between maltreatment, development and alterations in structure and function of stress-susceptible brain regions
  – Substantial alterations in connectivity and network architecture
• Less clear: how these changes directly link to psychopathology
Background

• Chronic stress:
  – Potentially adaptive changes of brain → can lead to psychopathology when adaptive responses/experiences so much differ as to become maladaptive
The Brain (101)
Whole Brain

Frontal Lobe

Somatosensory Cortex

Limbic System

Basal Ganglia (Striatum)

Hippocampus

Amygdala

Cerebellum

Corpus Callosum

Specific Brain Regions
Hippocampus

Hippocampus

• Involved in the formation and retrieval of memories, including autobiographical memories\(^1\)
  – *Place cells* provide an internal positioning system for the spatiotemporal representation of places, routes and associated experiences\(^2\)

• Most obvious target for potential effects of childhood maltreatment\(^3\)

1. Nadel, L, Campbell, J, & Ryan, L. Autobiographical memory retrieval and hippocampal activation as a function of repetition and the passage of time.
2. Moser, EI, Kropff, E & Moser, MB. Place cells, grid cells, and the brain’s spatial representation system.
Hippocampus

• Densely populated with glucocorticoid receptors\(^1\) → highly susceptible to damage from excessive levels of glucocorticoids (ex. cortisol)\(^2\)

2. Sapolsky, RM, Krey, LC, & McEwen, BS. Prolonged glucocorticoid exposure reduces hippocampal neuron number: Implications for aging.
Hippocampus

- **Adults:** smaller hippocampi in maltreated vs. nonmaltreated\(^1\)
  - But smaller effect in females
    - Possibly because of neuroprotective effects of estrogen\(^2\)

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2. McEwen, BS. Stress, sex, and neural adaptation to a changing environment: Mechanisms of neuronal remodeling. Andersen, SL &
Hippocampus

• Childhood/adolescence: evidence less strong of effects\(^1\)
  – Might not show until adolescence \(\rightarrow\) but studies have commonly combined both groups
  – May have “silent period” between childhood and adolescence with no discernable neurobiological differences\(^2\)

2. Andersen, SL & Teicher, MH. Delayed effects of early stress on hippocampal development.
Hippocampus

• May have potential **sensitive exposure periods**\(^1\)
  – Most significant: exposure between 3-5 years old; less degree at 11-13 years old\(^2\)
    • Early separation stress has much greater effects on synaptic density in hippocampus\(^3\)
  – Specifically associated with **reduction in volume** of portions of hippocampal that have been shown to be susceptible in both laboratory animals and humans\(^1,4-6\)

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3. Andersen, SL & Teicher, MH. Delayed effects of early stress on hippocampal development.
4. Andersen, SL & Teicher, MH. Stress, sensitive periods and maturational events in adolescent depression.
5. Pagliaccio, D et al. Stress-system genes and life stress predict cortisol levels and amygdala and hippocampal volumes in children.
6. Teicher, MH, Anderson, CM, & Polcari, A. Childhood maltreatment is associated with reduced volume in the hippocampal subfields CA3, dentate gyrus, and subiculum.
Hippocampus

- Smaller hippocampal volumes:
  - Mild cognitive impairment/Traumatic brain injury
  - Schizophrenia
  - Major depression
  - Posttraumatic stress disorder
  - Obsessive–compulsive disorder (OCD)
  - Chronic alcoholism
  - Antisocial personality disorder
  - Borderline personality disorder

- Larger hippocampal volumes:
  - Autism

- Preservation of hippocampal volume:
  - Bipolar disorder
  - Anorexia nervosa
  - Panic disorder
  - Attention-deficit/hyperactivity disorder (ADHD)
Amygdala

BRAIN FOOD

the amygdala
Amygdala

• Encoding of implicit emotional memories
  
• Detecting and responding to salient stimuli – ex. facial expressions and potential threats

Amygdala

- High density of glucocorticoid receptors on stress-susceptible pyramidal cells\(^1\)
- Postnatal developmental trajectory characterized by rapid initial growth \(\rightarrow\) more sustained growth to peak volumes between 9-11 years \(\rightarrow\) gradual pruning thereafter\(^2\)
- Also highly susceptible to exposure to early stress\(^3\)

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2. Uematsu, A et al. Developmental trajectories of amygdala and hippocampus from infancy to early adulthood in healthy individuals.
Amygdala

• Both psychological stressors and stress hormones $\rightarrow$ stimulate cells $\rightarrow$ increase in volume [hypertrophy]$^{1,2}$
  – Opposite of effects on hippocampus$^3$

• Hypertrophy, unlike hippocampal hypotrophy, **endures** long after cessation of the stressor$^4$

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1. Mitra, R et al. Stress duration modulates the spatiotemporal patterns of spine formation in the basolateral amygdala.
2. Vyas, A, Jadhav, S & Chattarji, S. Prolonged behavioral stress enhances synaptic connectivity in the basolateral amygdala.
4. Vyas, A, Pillai, AG & Chattarji, S. Recovery after chronic stress fails to reverse amygdaloid neuronal hypertrophy and enhanced anxiety-like behavior.
Amygdala

• Studies do not consistently show changes in maltreatment\(^1\)
  – If anything, majority showed a decrease
  – For decrease: had multiple forms of maltreatment; older; worse psychopathology

• Those studies that did show increase: early emotional and/or physical neglect
Amygdala

• **Early exposure** to stress sensitizes amygdala \( \rightarrow \) **volume reduction** with subsequent exposure to stress (ex. early childhood stress, then later exposed to combat \( \rightarrow \) increased risk to develop **PTSD**\(^1\)

• Longer-term study:\(^2\)
  – **Early** maltreatment \( \rightarrow \) increase in volume
  – **Later** exposure \( \rightarrow \) decrease in volume

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\(^1\) Teicher, MH & Samson, JA. Annual research view: Enduring neurobiological effects of childhood abuse and neglect.

\(^2\) Whittle, S et al. Childhood maltreatment and psychopathology affect brain development during adolescence.
Therefore:

- **Early** exposure to maltreatment or neglect → **initial increase** in amygdala volume (particularly noticeable during **childhood**)
- Early exposure may also **sensitize** the amygdala to further stress → result in a substantial **decrease** in amygdala volume (most noticeable in late adolescence or adulthood)
Cerebral Cortex

Cerebral Cortex

• Population of stress-susceptible (pyramidal) cells with a high density of glucocorticoid receptors → peaks during late adolescence/early adulthood\(^1\)
• Glucocorticoid receptors on (glial) cells that are most densely distributed during the neonatal period → gradually decline\(^2\)

Cerebral Cortex

• Therefore: **two periods** of heightened stress sensitivity
  1) Infancy to early childhood
     • **Sensory** and **motor** cortical regions develop earlier²
  2) Late adolescence to early adulthood³
     • Protracted developmental course of **prefrontal** cortical regions

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2. Lenroot, RK et al. Differences in genetic and environmental influences on the human cerebral cortex associated with development during childhood and adolescence.
Cerebral Cortex

• Overall effects (non region specific)
• Region specific
  – Higher order associations or polysensory cortex
  – Primary and secondary sensory cortex
Sheridan, MA et al.. Variation in neural development as a result of exposure to institutionalization early in childhood.
Cerebral Cortex

- Overall effects (non region specific)
  - From Bucharest Early Intervention Project\(^1\)
    - Early deprivation and continued institutional care:
      - 6.5% reduction in overall cortical grey volume
      - 6.4% reduction in overall white matter volume
  - Identically reared orphans who were randomly assigned to high-quality foster care (between 7-33 months old):
    - 6.4% reduction in grey matter volume
    - No difference between never institutionalized and adopted group in white matter volume

\(^1\) Sheridan, MA et al. Variation in neural development as a result of exposure to institutionalization early in childhood.
Cerebral Cortex

• Overall effects (non region specific)
  – Other studies have shown similar deleterious effects to children exposed to physical abuse, sexual abuse or witnessing domestic violence\textsuperscript{1-3}

Cerebral Cortex

- Region specific
  - Higher order associations or polysensory cortex\(^1,2\)
    - Attenuated development of the anterior cingulate cortex (ACC) was the most consistent findings → most have reductions on both sides
    - Attenuated dorsolateral prefrontal cortex
    - Attenuated orbitofrontal cortex
  - Total prefrontal grey matter volume appeared to be most sensitive to maltreatment between 14-16 years old

2. Andersen, SL & Teicher, MH. Stress, sensitive periods and maturational events in adolescent depression
Cingulate Cortex

Prefrontal Cortex
Cerebral Cortex

• Region specific
  – Higher order associations or polysensory cortex
  • These three regions: important role in decision-making and emotional regulation\(^1\)
    – Have a role in addiction\(^2\) → therefore, maltreatment may lead to brain changes that increase risk in addiction
  • Changes in those with a history of sexual abuse and psychotic disorder\(^3\)

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2. Koob, GF & Volkow, ND. Neurocircuitry of addiction.
Cerebral Cortex

• Region specific
  – Primary and secondary sensory cortex
    • Most reliable correlates of exposure to severe parental verbal abuse:¹
      – Grey matter volume alterations in left auditory cortex
      – Diminished integrity of the left arcuate fasciculus language pathway

¹ Tomoda, A et al.. Exposure to parental verbal abuse is associated with increased gray matter volume in superior temporal gyrus.
Cerebral Cortex

• Region specific
  – Primary and secondary sensory cortex
    • 3 fiber tracts
      – Left arcuate fasciculus: Critically involved in human language with lower verbal comprehension and verbal IQ scores
      – Left cingulum bundle: Correlated with depressive and dissociative symptoms
      – Left fornix: Associated with symptoms of anxiety and somatization

2. Choi, J et al.. Preliminary evidence for white matter tract abnormalities in young adults exposed to parental verbal abuse.
3. Rilling, JK et al. The evolution of the arcuate fasciculus revealed with comparative DTI.
Arcuate Fasciculus

Critically involved in human language with lower verbal comprehension and verbal IQ scores.
Cingulum Bundle
Correlated with depressive and dissociative symptoms
Fornix
Associated with symptoms of **anxiety** and **somatization**
Cerebral Cortex

• Region specific
  – Primary and secondary sensory cortex
  • Exposure to witnessing multiple episodes of domestic violence [especially between ages 7-13]\(^1\)
    – Left inferior longitudinal fasciculus: key component of the visual-limbic pathway → subserves emotional, learning and memory functions (specific to vision)\(^2\)
      » Correlated with depression, anxiety, somatization, ‘limbic irritability’ and neuropsychological measures of processing speed
    – Right lingual gyrus: early processing component of the visual system involved in visual memory for shapes, faces and letters
      » Involved in nonconscious processing [especially ages 11-13]\(^3\)

1. Choi, J et al. Reduced fractional anisotropy in the visual limbic pathway of young adults witnessing domestic violence in childhood.
3. Tomoda, A et al. Reduced visual cortex gray matter volume and thickness in young adults who witnessed domestic violence during childhood.
Inferior Longitudinal Fasciculus

Key component of the visual-limbic pathway → subserves emotional, learning and memory functions (specific to vision)

Correlated with depression, anxiety, somatization, ‘limbic irritability’ and neuropsychological measures of processing speed
Lingual Gyrus

Early processing component of the visual system involved in visual memory for shapes, faces and letters

Involved in nonconscious processing [especially ages 11-13]
Cerebral Cortex

• Region specific
  – Primary and secondary sensory cortex
    • Exposure to childhood sexual abuse was specifically associated with thinning of the portion of somatosensory cortex representing the clitoris and surrounding genital area

Heim, CM et al. Decreased cortical representation of genital somatosensory field after childhood sexual abuse.
Somatosensory Cortex

Cerebral Cortex

• Region specific
  – Primary and secondary sensory cortex
    • Exposed to single type of maltreatment: possible that brain regions and fiber tracts that process, convey adverse sensory input of the abuse may be specifically modified by this experience
    • Exposure to multiple types of maltreatment: more commonly produce alterations in corticolimbic regions involved in emotional processing and stress response

Cerebral Cortex

• Region specific
  – Primary and secondary sensory cortex

• Changes in maltreated individuals represent modifications or adaptations rather than nonspecific damage
  – Neuroplastic cortical adaptations may protectively shield a child from the sensory processing of the specific abusive experience
    » But thinning of the somatosensory cortex may lead to the development of behavioral problems
    » May lead to impairments in verbal comprehension, visual recall and emotional responses to witnessed events later in life

Cerebral Cortex

• Region specific
  – Corpus callosum: largest white matter tract$^1$
    • Critically important role in *inter-hemispheric communication* (particularly between contralateral cortical regions)
Corpus Callosum

Cerebral Cortex

• Region specific
  – Corpus callosum:
    • **Reduced** in maltreated children\(^1-3\) and adults\(^4,5\)
      – Reduced 2x greater in boys than girls\(^1-3,6,7\)
      – Most susceptible to neglect in males and to sexual abuse in females\(^3\)
    • Potential reversibility of the effects of early neglect on the corpus callosum\(^8\)

4. Teicher, MH et al. Childhood neglect is associated with reduced corpus callosum area.
6. Teicher, MH et al. Hurtful words: Association of exposure to peer verbal abuse with elevated psychiatric symptom scores and corpus callosum abnormalities.
8. Teicher, MH et al. Preliminary evidence for abnormal cortical development in physically and sexually abused children using EEG coherence and MRI.
9. Sheridan, MA et al.. Variation in neural development as a result of exposure to institutionalization early in childhood.
Cerebral Cortex

• Region specific
  – Striatum: inconsistent results (sometimes decreased, sometimes no change)
    • May not be sensitive to early life stress
    • Possibly different age and gender effects
Basal Ganglia (Striatum)

Cerebral Cortex

• Region specific
  – Cerebellum: should be **highly susceptible to early life stressors; research shows usually lower volume in maltreated**¹
    • Highest density of glucocorticoid receptors during the neonatal period in rats²
    • Postnatal neurogenesis occurs in cerebellum³
    • Exposure to high levels of glucocorticoids during early development exerted a more persistent effect on cerebellar than hippocampal volume in rats⁴

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¹. Teicher, MH & Samson, JA. Annual research view: Enduring neurobiological effects of childhood abuse and neglect.
³. Walton, RM. Postnatal neurogenesis: Of mice, men, and macaques.
⁴. Ferguson, SA, & Holson, RR. Neonatal dexamethasone on day 7 causes mild hyperactivity and cerebellar stunting.
Cerebellum

Cerebral Cortex

• Region specific
  – Cerebellum: should be highly susceptible to early life stressors; research shows usually lower volume in maltreated
    • Vermis in particular seems to be susceptible region
      » Autism
      » Schizophrenia
      » Bipolar disorder
      » MDD
      » ADHD

Differences in Structure and Function for Those Maltreated
Functional Differences

• Differences in response to facial expressions
  – Maltreated = increased amygdala reactivity to emotional faces
Amygdala

Functional Differences

• Altered response to threatening stimuli
  – Thalamus, visual cortex, anterior cingulate cortex, ventromedial prefrontal cortex, amygdala and hippocampus
  – Decreased integrity of fiber tracts
    • inferior longitudinal fasciculus, superior longitudinal fasciculus/arcuate fasciculus, uncinate fasciculus, cingulum bundle and fornix.
  – Therefore: most of the regions previously discussed are also involved in threat detection
Functional Differences

• Therefore: changes in brain regions may be adaptive modifications to trauma → enhanced threat detection, more rapid recognition of fearful stimuli\textsuperscript{1,2}
  – Circuit: \textbf{rapidly} responsive \textbf{nonconscious} subcortical path and a \textbf{slower conscious} cortical path to the amygdala
  – Maltreatment-related alterations in sensory cortex: diminish the influence of the conscious component favoring \textbf{rapid but less nuanced} response via the subcortical pathway

\textsuperscript{1} Teicher, MH & Samson, JA. Annual research view: Enduring neurobiological effects of childhood abuse and neglect.
\textsuperscript{2} Masten, CL et al. Recognition of facial emotions among maltreated children with high rates of post-traumatic stress disorder.
Functional Differences

• Differences in sensitive exposure periods of different regions
  
  – Range: hippocampus (3-5 years old) to prefrontal cortex (14-16 years old)

  • Therefore: Because multiple different regions involved in these circuits → can have multiple different reasons for same overall outcome
Functional Differences

• Reward anticipation
  – Areas involved: Many of the same ones we have just covered
  – Again, may of these regions affected in those with maltreatment
  – Overall: reduced response to anticipatory reward
  • May be adaptive: if decrease belief that an action will be rewarded, more likely to avoid (like avoiding things that lead to maltreatment)

Teicher, MH & Samson, JA. Annual research view: Enduring neurobiological effects of childhood abuse and neglect.
Network Architecture

• Maltreated individuals have **diminished** capacity to:
  – Regulate impulses and emotions
  – Accurately attribute thoughts and intentions to others
  – Be mindful of oneself in a social context

• Maltreated individuals have **increased**
  – Experience of internal emotions and cravings
  – Greater tendency to think about oneself and to engage in self-centered mental imagery

Teicher, MH & Samson, JA. Annual research view: Enduring neurobiological effects of childhood abuse and neglect.
Network Architecture

• Therefore: neurobiological explanations for why psychotherapy for these individuals focuses on:
  – Enhance emotional regulation
  – Correct misconceptions about self and others
  – Diminish focus on internal feelings and to reduce harmful self-centered thinking
Thoughts

Feelings ← → Behaviors
Summary

- There are many effects that come with maltreatment, including both direct and indirect effects of domestic violence.
- While there are clear associations between chronic trauma and the development of PTSD, maltreatment has far ranging consequences both in terms of cognitive development and the increased risk of a large variety of mental health disorders.
- The focus here has been primarily “organic” changes that come with being a part of domestic violence, however, we are increasingly learning about the direct and indirect psychological consequences of these events.
References

• Andersen, SL & Teicher, MH. Stress, sensitive periods and maturational events in adolescent depression. Trends in Neurosciences. 2008; 31: 183–191
References

• de Bellis, MD et al. Neuropsychological findings in childhood neglect and their relationships to pediatric PTSD. Journal of the International Neuropsychological Society. 2009;15: 868–878
• Bremner, JD et al. Magnetic resonance imaging-based measurement of hippocampal volume in posttraumatic stress disorder related to childhood physical and sexual abuse—a preliminary report. Biological Psychiatry. 1997; 41: 23–32
References


• Clark, K et al. White matter integrity, language, and childhood onset schizophrenia. *Schizophrenia Research*. 2012;138: 150–156


References


References

References

- Heim, CM et al. Decreased cortical representation of genital somatosensory field after childhood sexual abuse.


References

References

References

• Sapolsky, RM, Krey, LC, & McEwen, BS. Prolonged glucocorticoid exposure reduces hippocampal neuron number: Implications for aging. *Journal of Neuroscience*. 1985; 5: 1222–1227
References

References

Questions?

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