IMPACT OF POVERTY ON BRAIN DEVELOPMENT AND LEARNING

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The Real 21st-Century Problem in Public Education is Poverty

• A new study showing explosive growth in student poverty suggests we have misidentified the problem
  • The Washington Post, November 6, 2013, by Elaine Weiss
  • In 2000, ½ the student body in 4 states eligible for free or reduced meals
  • Just eleven years later – over half of public school students are poor in 17 states (all but two Southern states and most Western)
  • Student poverty is the dominant reality
    – in three of the biggest states – California, Texas and Florida
    – and nearly the majority in New York, Michigan and Illinois.

Why Now: Rapid Increase in Students from Poverty

• 33% increase in Title 1 Students in last 15 years
• 38% of population in 2001, now making up 51% of the population

Percentage of Low Income Students in U.S. Public Schools

Key Points

• Children raised in poverty are exposed to millions of fewer spoken words at home
• Income level negatively impacts cognitive functions
• There are links between family income and memory and attention
• Poverty is associated with chronic stress which can have a toxic effect on brain architecture
• ELL’s often have a triple jeopardy – language barrier to learning, history of poverty, learning disabilities
• Computer games designed to target the skills that are impacted can turn around some effects of poverty
The Brain is an Experience Dependent Organ

- What does that mean?
- In early development there is proliferation of connections
- As we age there is pruning – the brain gets better at fewer things (more rigid)
- Fiber tracts also build myelin to improve processing speed and efficiency as we learn and practice our new knowledge

All cognitive functions apparently involve distinctive networks – mapping out of those networks has been one ongoing goal of recent neuroscience research.

How Experience Changes the Brain (Gopnik, 2015)

- Early in development proliferation prevails – young children make many more new connections than adults
- Later in development pruning is more important – adults shift from a young brain that is good at learning to an older brain that is more effective and efficient but more rigid.
- We get better and better at fewer and fewer things
Synaptic pruning fine-tunes *synaptic connections* – *cortex thins*

But the cortex is only part of the story – fiber tracts become more myelinated through learning *(Fields, 2015 Nature Reviews Neuroscience)*

Lebel, et al. 2008

*Language Experiences*
There are links between family income and memory and attention

Effect Sizes

- Among children from lower income families, small differences in income were associated with relatively large differences in surface brain area.
- Among children from higher income families, similar income increments were associated with smaller differences in surface area.
Income Effects on Brain Development (Noble et al, 2015)

- Among low income families, small differences in income were associated with relatively large differences in surface area,
- Among children from higher income families, similar income increments were associated with smaller differences in surface area.

The relationships were most prominent in regions supporting language, reading, executive functions and spatial skills; surface area mediated socioeconomic differences in certain neurocognitive abilities.

Brain structure and poverty (Noble et al, 2015)

- Brain Structure and income level relationships were most prominent in regions supporting language, reading, executive functions and spatial skills.

Noble et al 2015 Conclusion

- This research implies that income relates most strongly to brain structure among the most disadvantaged children.

A month later – Gabrielli’s Lab at MIT

- Published research clarifies the income/achievement gap
- showing that High Income versus Low Income achievement differences directly correlate to measures of cortical thickness in adolescents
Neuroanatomical Correlates of the Income-Achievement Gap


By October see differential effects of SES on kinds of memory (working versus procedural memory)

So... SES does not affect ability to learn or intelligence

- Rather SES affects those types of learning important for academic success
- But why????

And two months ago—Reuters
Health Mon Jul 20, 2015 3:32pm

- Effect of poverty on brains may explain poor kids' lower test scores
- 20 percent of the gap in test scores between poor children and middle-class children may be a result of poor brain development in the frontal and temporal lobes

Stress and the brain

Stress

- death or serious illness of a loved one,
- a frightening accident,
- an acrimonious parental separation or divorce,
- persistent discrimination,
- or other serious events

Tolerable stress

- Has the potential to negatively affect the architecture of the developing brain,
- but if occurring over limited time periods
  - Allows for the brain to recover and thereby reverse potentially harmful effects
  - Always in the context of ongoing, supportive relationships with adults.

Toxic Stress

- Strong, frequent, or prolonged activation of the body’s stress management system.
  - Stressful events that are chronic, uncontrollable, and/or experienced without children having access to support from caring adults
  - For example, severe, chronic abuse, especially during early, sensitive periods of brain development
Effects on Brain Development

• The neural circuits for dealing with stress are particularly malleable (or “plastic”) during the fetal and early childhood periods
  – the regions of the brain involved in fear, anxiety, and impulsive responses may overproduce neural connections
  – those regions dedicated to reasoning, planning, and behavioral control may produce fewer neural connections

Damage to health and well-being

• Extreme exposure to toxic stress changes the stress response system
  – Responds at lower thresholds to events that might not be stressful to others,
  – Activates more frequently and for longer periods than is necessary, like revving a car engine for hours every day.

Both adrenaline and cortisol are produced under normal circumstances and help prepare the body for coping with stressors.

Biology

(1) the sympathetic-adrenomedullary (SAM) system, which produces adrenaline in the central part of the adrenal gland

(2) the hypothalamic-pituitary-adrenocortical (HPA) system, which produces cortisol in the outer shell of the adrenal gland

LANGUAGE AND READING AREAS (TWO OF THE AREAS MOST IMPACTED BY POVERTY) ARE ACTIVATED AFTER SIX WEEKS OF FAST FORWARD TRAINING

Typically reading children
Children with dyslexia before remediation
Children with dyslexia after remediation

Gabrieli, 2009
Maternal Stress during pregnancy is also pernicious

- Significant maternal stress during pregnancy and poor maternal care during infancy
  - affects the developing stress system
  - alters genes that are involved in brain development.

Socioeconomic Risk Factors NCES Found Effects Kindergarten Readiness

- having a single parent,
- having a mother who didn’t graduate high school,
- living below the federal poverty line, and
- living in a household where English was not spoken as the first language

Risk Factor Effect on Academic Skill Level in Reading and Math

Risk Factor Effect on Working Memory

Bernstein, S. et al. (2014)
Nutrition and the developing brain: nutrient priorities and measurement

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Brain Requirement for the Nutrient</th>
<th>Predominant circuitry or process affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>Energy</td>
<td>Cell proliferation, cell differentiation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Synaptogenesis</td>
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<tr>
<td></td>
<td></td>
<td>Cortical</td>
</tr>
<tr>
<td>Iron</td>
<td>Myelin</td>
<td>White matter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neuronal and glial energy metabolism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hippocampal-frontal</td>
</tr>
<tr>
<td>Zinc</td>
<td>DNA synthesis</td>
<td>Autonomic nervous system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neurotransmitter release</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Myelination</td>
</tr>
<tr>
<td>Copper</td>
<td>Neurotransmitter synthesis, neuronal and glial energy metabolism, antioxidant activity</td>
<td>Cerebellum</td>
</tr>
<tr>
<td>LC-PUFAs</td>
<td>Synaptogenesis</td>
<td>Eye</td>
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<td>Choline</td>
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<td>DNA methylation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Myelination</td>
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</tbody>
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For SPED Students

- School districts are now required to demonstrate RDA (Results Driven Accountability) for children who qualify for Special Education
  - This means the academic performance of children in SPED programs is required
  - No longer is compliance alone satisfactory

Adverse Childhood Experiences (ACES) (n =1007) [Jimenez et al, 2016]

<table>
<thead>
<tr>
<th>Variable %</th>
<th>(No.)</th>
<th>Total ACEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child maltreatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological</td>
<td>16 (162)</td>
<td>0 45 (451)</td>
</tr>
<tr>
<td>Neglect</td>
<td>13 (132)</td>
<td>1 27 (275)</td>
</tr>
<tr>
<td>Physical</td>
<td>35 (154)</td>
<td>2 16 (158)</td>
</tr>
<tr>
<td>Sexual</td>
<td>0.6 (6)</td>
<td>3 8 (84)</td>
</tr>
<tr>
<td>Household dysfunction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal depression</td>
<td>12 (121)</td>
<td>5 1 (11)</td>
</tr>
<tr>
<td>Substance use</td>
<td>15 (149)</td>
<td>6 0.3 (3)</td>
</tr>
<tr>
<td>Incarceration</td>
<td>18 (181)</td>
<td></td>
</tr>
<tr>
<td>Violence toward mother</td>
<td>11 (111)</td>
<td></td>
</tr>
</tbody>
</table>

Jimenez et al. Adverse Experiences in Early Childhood (ACES) and Kindergarten Outcomes

Table 3 Teacher Ratings of Below Average Academic Skills – percentages [Jimenez et al, 2016]
Table 5. Teacher Ratings of Behavior – Percentages (Jimenez et al, 2016)

<table>
<thead>
<tr>
<th></th>
<th>0 Aces</th>
<th>1 Aces</th>
<th>2 Aces</th>
<th>3 or More Aces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention Problems</td>
<td>0.00%</td>
<td>5.00%</td>
<td>10.00%</td>
<td>20.00%</td>
</tr>
<tr>
<td>Social Problems</td>
<td>15.00%</td>
<td>25.00%</td>
<td>10.00%</td>
<td>5.00%</td>
</tr>
<tr>
<td>Aggressive Behavior</td>
<td>25.00%</td>
<td>15.00%</td>
<td>10.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

A summary view of effects of Poverty, Stress and ACES (Sheridan and McLaughlin, 2016)

ELL enrollment in schools more than doubled between 1997 and 2008 (National Clearinghouse for English Language Acquisition, 2010).
Second Language Learning is very good for the brain

At the Institute for Learning and Brain Sciences at the University of Washington, 9-month-olds listen to Mandarin Chinese in play sessions with native speakers of Mandarin. On this week’s podcast, we’ll hear how some psychologists say being bilingual may actually be good for children’s cognitive development.

http://www.npr.org/player/v2/mediaPlayer.html?action=1&t=1&islist=false&id=135043787&m=135106090

Think of these neural clusters as keys on a piano

- Each language has its unique keyboard.
- A child raised with English records a keyboard of the 44 speech sounds or phonemes of English.
- A child raised with Spanish records a keyboard of the 26 phonemes of Spanish.
- Learning a second language requires the brain to build new “keys” — clusters or sets of neurons — to access the new language accurately and quickly.

English Language Learners: The Challenge

- The sounds of English (phonemes) don’t all exist in other languages and must be learned and their cortical representations must develop.
- Unlike some other languages, English is not transparent — written English has a variety of rules controlling pronunciation (phonemes) for different text (graphemes).

Disadvantages ELL Students May Face

- Parenting challenges associated with non-conventional work hours
- Cognitive, language and brain effects of poverty — see especially Noble, 2005 and 2015
- Cognitive, language and brain effects of stress
- Cultural isolation when in ELL classes
And, ELL students often have a high proportion of Unidentified Learning Disabilities

- Standardized test scores alone cannot distinguish between learning disabilities and other factors—
  - such as a student’s low level of proficiency in his or her first language,
  - limited prior schooling, and
  - low levels of English proficiency—that may cause an English learner student to perform below standards

Establishing English Proficiency as early as possible is essential

- ELL children who become fully proficient in English,
- And who do so earlier in their educational career,
- Do better later in school than those who continue to struggle with English proficiency (Halle, Hair, Wandner, McNamara, & Chien, 2012).

Solutions: Neuroscience – Moving from Why to What and How

- Positive experiences after infancy have been shown to compensate to some degree for the negative behavioral consequences
  - Being exposed to an environment rich in opportunities for exploration and social play,
  - Caring and positive relationships with adults
- Computer activities designed to target the skills that are impacted can turn around some effects of poverty
  - Fast ForWord exercises, because of their specific emphasis on language, attention and memory are particularly effective and offer a cost effective valuable solution
A Meta-Analysis of the Research

- IS NEUROSCIENTIFIC RESEARCH USEFUL FOR EDUCATORS?
- DOES THE CONTENT OF THE INTERVENTION MATTER?
- HOW LONG-LASTING ARE THE REMEDIAL GAINS IN THE BRAIN?

Neuroscientific research shows that improved behavioral performance is coupled with change in – both brain function and brain anatomy.

Especially in the study of dyslexia, neuroscientific studies have illuminated
- The location of aberrant brain functions,
- This enables us to specify the models of the impairment.

The Role of Neuroscience Technology

- Well designed neuroscience-based technology
- builds the underlying capacities that are reduced in some children of poverty or with learning issues

And the Brain Structures affected most by Poverty

LANGUAGE AND READING AREAS ARE ACTIVATED AFTER SIX WEEKS OF FAST FORWARD TRAINING

Typically reading children

Reading Impaired Children before remediation

Reading Impaired Children after remediation

Gabrielli, 2009

Left anterior inferior frontal gyrus IFG

Angular Gyrus AG

Left Medial Temporal Gyrus

Visual Word Form Area

IS NEUROSCIENTIFIC RESEARCH USEFUL FOR EDUCATORS? (Ylinen and Kujala, 2015)
What Works Clearinghouse

#1 Rated Intervention for improvement in English Language Development

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Improvement Index</th>
<th>Effectiveness Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast ForWord®: Language</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Instructional Conversations and Literature Logo</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Read Well®</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Peer Tutoring and Response Groups</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Vocabulary Improvement Program for English Language Learners (VIP)</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Bilingual/Crosslingual Reading and Composition (BCRBC)</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Arthur</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Read Naturally®</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Enhanced Proactive Reading</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
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Effects of Fast ForWord on Attentional Skills


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Improving Fluid Intelligence with Training on Working Memory

Susanne M. Jaeggi, Martin Buschkuehl, John Jonides, and Walter J. Perrig.


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Working Memory Training Improves Reading Processes in Typically Developing Children

Students who believe intelligence is malleable (growth mind-set) earned higher math grades in the fall of 7th grade than those who believe in static intelligence (fixed mind-set) even though the groups had equivalent math achievement test scores in the sixth grade. From Implicit Theories of Intelligence Predict Achievement. LS Blackwell et al., CHILD Devel., Vol. 78, No. 1