Plenary

Motor System Development, Environment, and Experience: Implications for NICU Care

21st Annual Gravens High Risk Infant Conference
Clearwater, Florida, 30 January 2008

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Department of Psychiatry
Children's Hospital Boston, Harvard Medical School

The Challenge

A World-wide increase in prematurity rates.

A In the US, annually >12% of births are pre-term. African-American families > 18%; highest prematurity rate in world.

A More than 50% of children born preterm show later learning disabilities, attention deficits, behavior problems, emotional issues, and school failure, often associated with awkward or impaired motor system performance.

H. Als, 2007

Dissection showing the advanced development of the superficial muscles in a 20 mm embryo estimated to be 8 weeks old post conception.

In Gesell A. The embryology of behavior. Westport, CT: Greenwood Press 1945; after Bardeen, CR, Lewis WH. The development of the limbs, body-wall and back. Amer J Anatomy, 1901-1902, 1, 1-37+1plates

H. Als, 1982

The earliest recorded fetal movement. Fetus at 8.5 weeks.


H. Als, 1986

Menstrual Age (w) 

<table>
<thead>
<tr>
<th>Skin-Areas Sensitive to Stimulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
</tr>
<tr>
<td>8-9.5</td>
</tr>
<tr>
<td>10-10.5</td>
</tr>
<tr>
<td>10.5</td>
</tr>
<tr>
<td>10.5-11</td>
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<tr>
<td>11</td>
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<tr>
<td>11.5</td>
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<tr>
<td>11-12</td>
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<tr>
<td>13</td>
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<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>17</td>
</tr>
</tbody>
</table>


H. Als, 1986

Early Fetal Development

At Seven Weeks

About 2.5 cm long, weighing about 2 g


H. Als, 1978
Somatosensory cortex with representation of the various parts of the body surface (sensory homunculus).

More cortical tissue is devoted to face, hand and foot than to other parts of the body.


Early Fetal Development
15 weeks old
About 8 cm long, weighing about 25g

H. Als, 1978

Early Fetal Development
18 weeks old

H. Als, 1978

Early Fetal Development
20 weeks old

H. Als, 1978

Human Neuro-Sensory Development
Sequential Pattern of Sensory Development

<table>
<thead>
<tr>
<th>Sensory</th>
<th>Post Menstrual Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin (Touch)</td>
<td>7.5 - 18</td>
</tr>
<tr>
<td>Taste and Smell</td>
<td>12 - 14</td>
</tr>
<tr>
<td>Audition</td>
<td>18 - 35</td>
</tr>
<tr>
<td>Movement and Position</td>
<td>20 - 25</td>
</tr>
<tr>
<td>Vision</td>
<td>38 ~ 2y CA</td>
</tr>
</tbody>
</table>


H. Als, 1995
H. Als, PhD  Motor System Development, Environment, and Experience: Implications for NICU Care
21st Gravens Conference, Clearwater, FL 30 January 2008

Drawing by Tom Prentiss.
H. Als, 1981


The Human Species-Specific Neuro-Biological Adaptation, Material Culture, requires the co-evolution of highly complex brain structures to support not only highly complex cognitive, but also highly complex affective and social-interactive skills and capacities.


D. H. Hubel, The Brain, Scientific American, 1979

The Brain and Development

All sensory experience results in neural activity and impacts on the developing brain's structure.

Consequences are greatest when strong and unexpected experiences impact on the brain at a stage of its most rapid development; this results in a vulnerable, perhaps even critical period of brain development.

H. Als, 1979

H. Als, 2005

H. Als et al, IBD, 1988
H. Als, PhD  Motor System Development, Environment, and Experience: Implications for NICU Care
21st Gravens Conference, Clearwater, FL 30 January 2008

Brain Electrical Activity Mapping (BEAM)
SPM Group Difference Maps FT / PT / PPT: N= 148

Duffy, Als, McAnulty, CDdev, 1998

3D Magnetic Resonance Imaging (MRI), Cerebral Tissue Segmentation


Neuropsychological Battery at Eight Years Post EDC

Preterm-born Child Test Profile at 8 Years CA (26 wPCA at birth)
Verbal and Performance IQ: 115; Superior Performance: Serial Processing & Language Tests; Low Performance: Simultaneous Processing & Non-Verbal Tests


Statistical Parameter Map of Group Differences in Cerebral Tissue Volumes

Preterm vs. Full-Term Anatomical Differences at 8 Years Corrected Age


Three Promised Environments

Hofer, 1985

The Mother's Womb, her Breast and Body, the Species' Social Group

NICU Environment Incubators and Machines Parent Separation Painful Touch Many Hands

H. Als, 2007

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Children's Hospital Boston, Enders Pediatric Research Laboratories, EN-107, 320 Longwood Avenue, Boston, MA 02115,
Ph: 617-355-8249 Fax: 617-730-0224 Email: heidelise.als@childrens.harvard.edu
H. Als, PhD  Motor System Development, Environment, and Experience: Implications for NICU Care  
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Synactive Model of Developmental Care

All infants count on:
- Security
- Protection
- Intimacy

H. Als, 1998

Environment
- Community and setting
- Path to the infant
- Care area
- Bedspace and bedding
- Infant’s immediate contact ecology


Behavior
- Continuous expression of brain function
- Always available to be observed
- Guide for environment, interaction and care

H. Als, 2005

Autonomic System
- Breathing
- Color
- Visceral System


H. Als, 2001

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Ph: 617-355-8249 Fax: 617-730-0224 Email: heidelise.als@childrens.harvard.edu
Motor System
- Tone
- Posture
- Movement

State System and Regulation
- Range
- Robustness
- Transitions

Regulatory System
- Efforts
- Strategies
- Success

NIDCAP Observation
- Infant Behavior
  - At Rest
  - In Interaction with a Caregiver
  - Returning to Rest
  - On a 24-Hour Ongoing Basis

~ The Individual Infant’s Behavior ~
- Guide for
  - Environmental structuring
  - Bedside, care equipment and supply use and arrangement
  - All care planning and interaction
  - Parent support, inclusion, partnership

Comfortable, Soothing Bedding
H. Als, PhD  Motor System Development, Environment, and Experience: Implications for NICU Care 
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**Summary of NIDCAP Study Findings**

<table>
<thead>
<tr>
<th>4 RCT</th>
<th>2 RCT*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
<td>a / b (%)</td>
<td>a / b (%)</td>
</tr>
<tr>
<td>Lung</td>
<td>2 / 4 (50%)</td>
<td>4 / 4 (100%)</td>
</tr>
<tr>
<td>Feeding</td>
<td>2 / 2 (100%)</td>
<td>4 / 4 (100%)</td>
</tr>
<tr>
<td>Growth</td>
<td>3 / 4 (75%)</td>
<td>3 / 4 (75%)</td>
</tr>
<tr>
<td>Hosp Stay</td>
<td>3 / 4 (75%)</td>
<td>4 / 4 (100%)</td>
</tr>
<tr>
<td>Brain</td>
<td>3 / 3 (100%)</td>
<td>4 / 4 (100%)</td>
</tr>
</tbody>
</table>

* RCT involving non-intubated, low-risk AGA preterms, 28-34w GA.

**Note:** No study identified any adverse effects nor trend in adverse direction in any domain or variable measured.

**Very High Risk Preterm Infants < 29w GA; N= 107**

**Medical Outcome Variables, 2w CA (1)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n = 51)</th>
<th>Experimental (n = 56)</th>
<th>χ²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator Days</td>
<td>48 (18)</td>
<td>39 (16)</td>
<td>8.37</td>
<td>0.005</td>
</tr>
<tr>
<td>Oxygen Days</td>
<td>106 (13)</td>
<td>60 (12)</td>
<td>5.36</td>
<td>0.02</td>
</tr>
<tr>
<td>Gavage Days</td>
<td>57 (9)</td>
<td>53 (13)</td>
<td>0.62</td>
<td>0.43</td>
</tr>
<tr>
<td>Hospital Days</td>
<td>128 (109)</td>
<td>84 (21)</td>
<td>7.91</td>
<td>0.005</td>
</tr>
<tr>
<td>Discharge Age (w, LMP)</td>
<td>44 (12)</td>
<td>39 (5)</td>
<td>0.00</td>
<td>0.99</td>
</tr>
<tr>
<td>Daily wt. gain to 2w CA (g)</td>
<td>20 (6)</td>
<td>23 (6)</td>
<td>7.52</td>
<td>0.006</td>
</tr>
<tr>
<td>Weight at 2w CA (kg)</td>
<td>3.12 (0.66)</td>
<td>3.39 (0.65)</td>
<td>4.57</td>
<td>0.04</td>
</tr>
<tr>
<td>Length at 2w CA (cm)</td>
<td>47.31 (3.6)</td>
<td>47.61 (3.8)</td>
<td>0.17</td>
<td>0.68</td>
</tr>
<tr>
<td>Head Circum. 2w CA (cm)</td>
<td>35.15 (2.2)</td>
<td>35.84 (2.1)</td>
<td>2.82</td>
<td>0.09</td>
</tr>
<tr>
<td>Ped Complication Scale</td>
<td>54.67 (6.7)</td>
<td>57.07 (6.9)</td>
<td>3.35</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Means (SD). Corrected Age (CA). Brown-Forsythe One-Way Analysis of Variance: *p*, 2-tailed; Note: *p* (probability) in bold *0.05 level.


**Very High Risk Preterm Infants < 29w GA; N= 107**

**Medical Outcome Variables, 2w CA (2)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n = 51)</th>
<th>Experimental (n = 56)</th>
<th>χ²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td>None, Present</td>
<td>37, 13</td>
<td>46, 27</td>
<td>0.03</td>
</tr>
<tr>
<td>Intraventricular Hemorrhage</td>
<td>None, Grade 1/2/3/4</td>
<td>29, 8, 6, 3</td>
<td>46, 2, 6, 0</td>
<td>12.92</td>
</tr>
<tr>
<td>Bronchopulmonary Dysplasia</td>
<td>None/ Stage I/II/III/IV</td>
<td>8, 11, 12, 17, 3</td>
<td>9, 17, 24, 5</td>
<td>12.68</td>
</tr>
<tr>
<td>Retinopathy of Prematurity</td>
<td>None/ Stage I+II/III+IV</td>
<td>26, 23, 1, 1</td>
<td>31, 24, 1, 0</td>
<td>1.23</td>
</tr>
</tbody>
</table>

Chi Square Test: *q*, 2-tailed. Note: *p* (probability) in bold *0.05 level.

**Very High Risk Preterm Infants < 29w GA; N = 107**  
APIB System Scores, 2wCA

<table>
<thead>
<tr>
<th>Variable</th>
<th>C</th>
<th>E</th>
<th>F*</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomic system</td>
<td>6.67</td>
<td>5.55</td>
<td>0.35</td>
<td>0.0001</td>
</tr>
<tr>
<td>Motor system</td>
<td>6.62</td>
<td>5.46</td>
<td>0.35</td>
<td>0.0001</td>
</tr>
<tr>
<td>State system</td>
<td>5.87</td>
<td>5.02</td>
<td>0.35</td>
<td>0.0001</td>
</tr>
<tr>
<td>Attention system</td>
<td>7.19</td>
<td>6.68</td>
<td>0.35</td>
<td>0.0001</td>
</tr>
<tr>
<td>Self-regulation</td>
<td>6.61</td>
<td>5.62</td>
<td>0.35</td>
<td>0.0001</td>
</tr>
<tr>
<td>Examiner facilitation</td>
<td>7.03</td>
<td>5.93</td>
<td>0.35</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Means (SD). Corrected Age (CA). Brown-Forsythe One-Way Analysis of Variance: F*, 2-tailed; Note: p (probability) in bold Ø 0.05 level. Als et al. NIH NIDRR NCRI Study, in prep.

**Family Outcome: Parenting Stress Index (PSI) and Mother’s View of the Child (MVC)**  
Very High Risk < 29w GA: Preterm Infants at 42w LMP

MANCOVA:
- Group: F=2.41; df=5,66; p<.05  
- Site: F=1.48; df=10,132; p=.15  
- G x S: F=0.57; df=10,132; p=.83

Significance Levels: * p<.05 ** p<.01 *** p<.001  
Als et al. DevBehPedia, 2003

**Very High Risk Preterm Infants < 29w GA; N = 92**  
Bayley Scales of Infant Development, 9m CA

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n=42)</th>
<th>Experimental (n=50)</th>
<th>F*</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDI</td>
<td>96.55 (21.42)</td>
<td>116.24 (22.12)</td>
<td>23.29</td>
<td>0.0001</td>
</tr>
<tr>
<td>PDI</td>
<td>84.29 (19.24)</td>
<td>99.18 (17.30)</td>
<td>11.08</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Corrected Age (CA); Mental Developmental Index (MDI), Psychomotor Developmental Index (PDI). Results Means (SD) MDI and PDI. Mean = 100; SD = 15. Brown-Forsythe One-Way Analysis of Variance: F*, 2-tailed. Chi Square Test: χ², 2-tailed. Note: p (probability) in bold Ø 0.05 level. Als et al. NIH NIDRR NCRI Study, in prep.

**APIB System Scores 42w LMP - Low-Risk Infants 28-32w LMP N=30**

<table>
<thead>
<tr>
<th>Variable</th>
<th>C (n=14)</th>
<th>E (n=16)</th>
<th>F*</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomic System</td>
<td>5.56</td>
<td>4.59</td>
<td>2.41</td>
<td>0.12</td>
</tr>
<tr>
<td>Motor System</td>
<td>6.29</td>
<td>4.70</td>
<td>2.67</td>
<td>0.12</td>
</tr>
<tr>
<td>State System</td>
<td>5.22</td>
<td>4.62</td>
<td>1.01</td>
<td>0.32</td>
</tr>
<tr>
<td>Attention System</td>
<td>6.91</td>
<td>6.54</td>
<td>0.09</td>
<td>0.77</td>
</tr>
<tr>
<td>Self-Regulation</td>
<td>6.11</td>
<td>4.94</td>
<td>0.001</td>
<td>0.99</td>
</tr>
<tr>
<td>Examiner</td>
<td>6.89</td>
<td>5.74</td>
<td>3.37</td>
<td>0.08</td>
</tr>
<tr>
<td>Facilitation</td>
<td>1.76</td>
<td>1.67</td>
<td>3.37</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Means (SD). Brown-Forsythe One-Way Analysis of Variance: F*, 2-tailed; probability (p) Ø 0.05 level. Als et al, DevBehPedia, 2004

**EEG Coherence Measures 42w LMP Low-Risk Infants**

N=30  
(C 14 / E 16)  
28-32w LMP at Birth

Wilks’λ; Λ=0.45; F=7.69; df=4,25; P = .0001  
Coherence background: blue ‑ decreased / orange ‑ increased; Arrows: green ‑ decreased / red ‑ increased  
Als et al. Pedia, 2004

**Diffusion Tensor Imaging at 42w LMP**

Low-Risk Infants, 28-32w LMP, N=23 (C=8/E=15)  
Control Group Infant Experimental Group Infant

Anisotropy E1/E3 - Threshold Ø1.3  
Black Arrows: Frontal White Matter  
White Arrows: Internal Capsule, posterior limbs  
Als et al, Pedia, 2004
Bayley Scales of Infant Development II, at 9 Months CA (N=24)
Low-Risk Infants 28-32w LMP

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n=13)</th>
<th>Experimental (n=11)</th>
<th>F*</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDI</td>
<td>94.85 (9.22)</td>
<td>109.55 (7.23)</td>
<td>19.14</td>
<td>0.0002</td>
</tr>
<tr>
<td>PDI</td>
<td>89.23 (14.88)</td>
<td>107.00 (9.28)</td>
<td>12.86</td>
<td>0.002</td>
</tr>
<tr>
<td>Orientation/Engagement</td>
<td>56.92 (27.97)</td>
<td>70.55 (21.62)</td>
<td>6.61</td>
<td>0.19</td>
</tr>
<tr>
<td>Emotional Regulation</td>
<td>39.31 (27.42)</td>
<td>66.91 (22.89)</td>
<td>7.25</td>
<td>0.01</td>
</tr>
<tr>
<td>Motor Quality</td>
<td>22.62 (21.57)</td>
<td>56.64 (31.05)</td>
<td>9.38</td>
<td>0.007</td>
</tr>
<tr>
<td>BRS Total Score</td>
<td>38.69 (23.04)</td>
<td>72.64 (16.13)</td>
<td>17.87</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

CA-Corrected Age; MDI-Mental Developmental Index; PDI-Psychomotor Developmental Index; BRS-Behavior Rating Scales. Results: Means (SD); MDI and PDI 100 (15). Brown-Forsythe One-Way Analysis of Variance: F*, 2-tailed. Chi Square Test: χ², 2-tailed. Note: p (probability) in bold ≤ 0.05 level. H. Als, et al. Pediatrics, 2004

Summary Thoughts
A NIDCAP Care is evidence-based, best NICU practice and earliest brain care
A System change requires changing hearts, minds, eyes, hands, and political will
A One brain for life - all experience matters. It matters how we care for ourselves and for the each infant and family in our care.

H. Als, 2007

3-DVD Teaching Set

DVD 1: The Science of Preterm Infant Development
DVD 2: Clinical Practices for Special Care Nurseries

VIDA Health Communications, Inc. Cambridge MA 2006
Lisa McElaney, Principal Investigator
Allie Humenuk, Producer
Katherine Rose, Co-Producer
Funded by NICHD, Washington DC USA

H. Als, 2007

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