

Printing Note: This handout is a blend of slides for both my keynote and breakout sessions, so if you plan to attend both, you needn't print the Keynote handout.

What's Going on in There? Brain Development & Early Learning

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Why know about the brain?

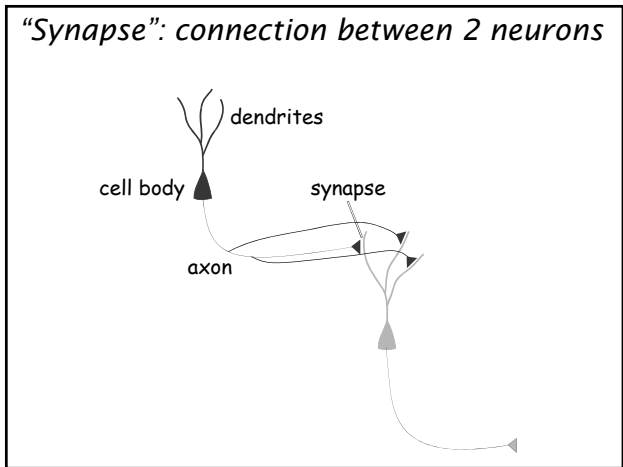
- ◆ Enhances understanding of child development, parenting and educational practices.
- ◆ We influence it: experience literally reshapes the brain, which neuroscientists call "plasticity."
- ◆ Long-lasting effects: there really are critical periods in brain development.
- ◆ Legitimizes investment in early childhood.

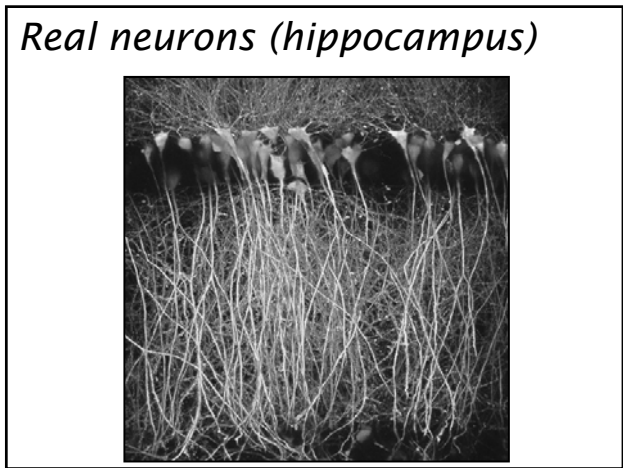


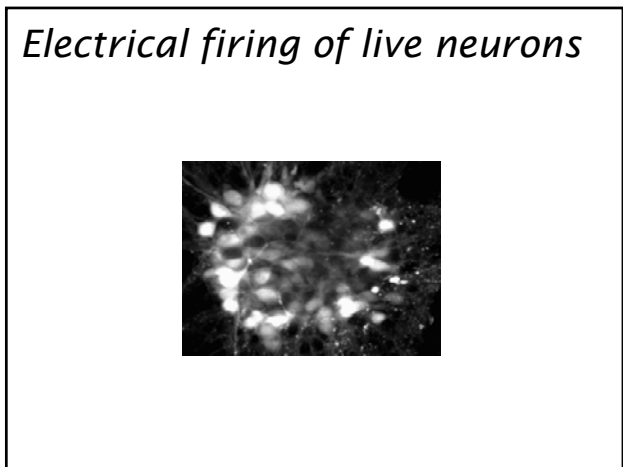
Plasticity

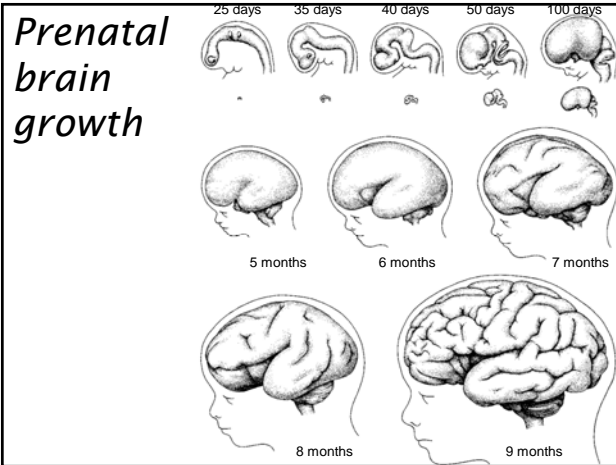


- ◆ The environment accounts for roughly 50% of brain and mental development.
- ◆ Experience alters brain structure according to two "activity-dependent" rules:
 - "Cells that fire together, wire together."
 - "Use it or lose it."
- ◆ Plasticity is much greater in childhood than later life:
- ◆ Critical periods correspond to phases of synaptic exuberance.






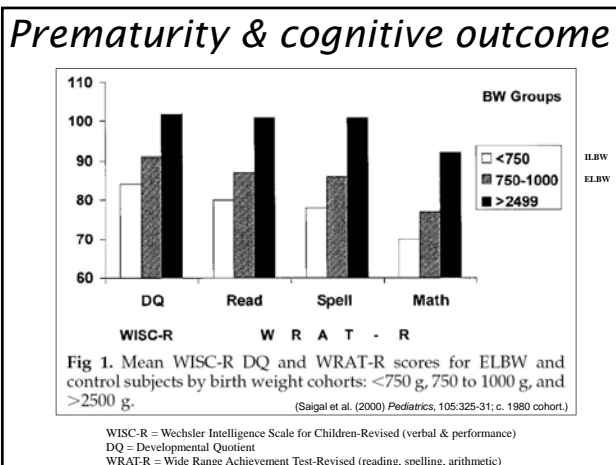




Prenatal experience



- ◆ Prenatal experience contributes up to 20% of IQ variance.
- ◆ Prenatal growth also a predictor for later diabetes & cardiovascular disease. The fetal body becomes programmed to a certain level of nutrition; changes after birth are maladaptive.
- ◆ From a public health perspective, improved prenatal care (reducing prematurity) is the most cost-effective strategy for improving children's later brain function.

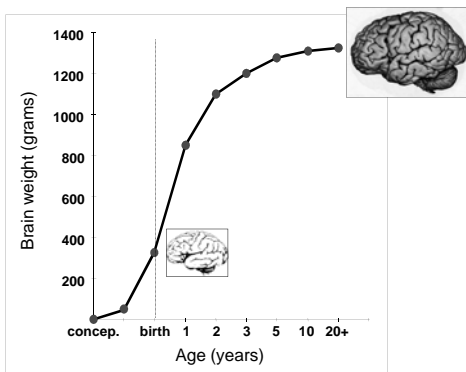


Prenatal influences on the brain

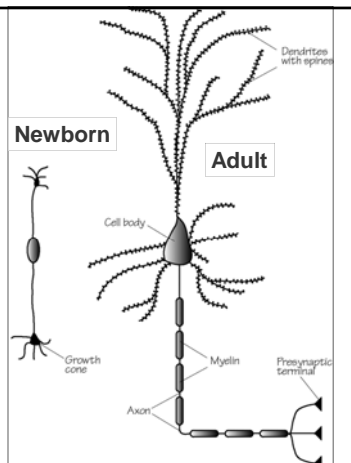
- ◆ Sensory/motor experience
- ◆ Maternal nutrition
- ◆ Alcohol, cigarettes, and illicit drugs
- ◆ Environmental toxins
- ◆ Maternal illness
- ◆ Medications
- ◆ Radiation
- ◆ Maternal stress
- ◆ Infections



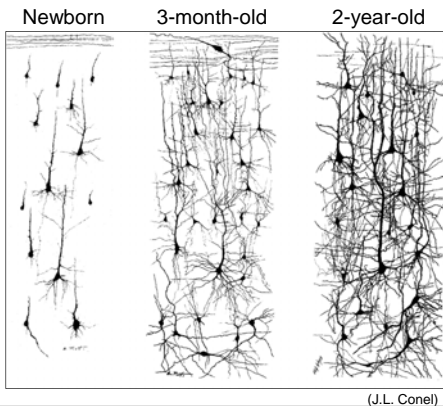
Most brain growth is postnatal



How do neurons grow up?



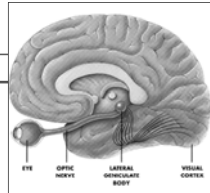
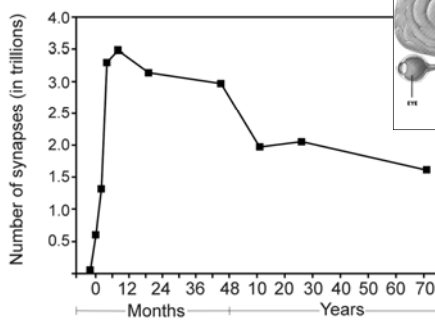
Growth of dendrites



(J.L. Conel)

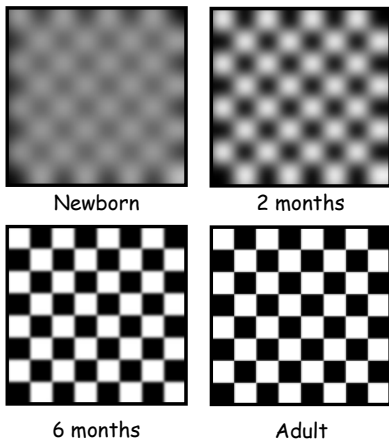
Synapse production & pruning

Visual cortex



(Data from Peter Huttenlocher)

Maturing visual acuity



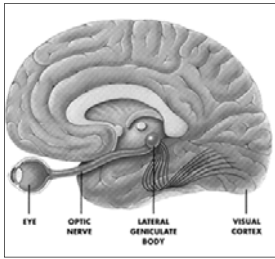
Newborn

2 months

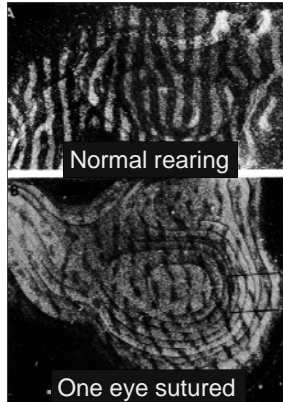
6 months

Adult

Effect of early visual experience

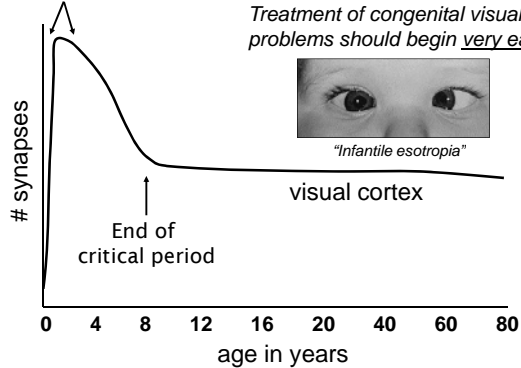


D. Hubel,
T. Wiesel



Pruning & the critical period

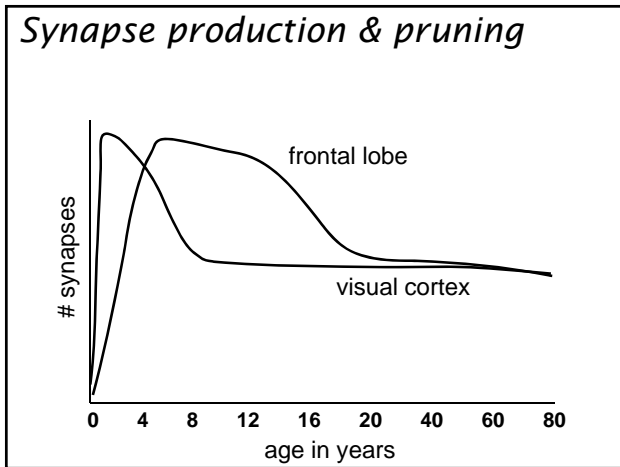
Most sensitive phase

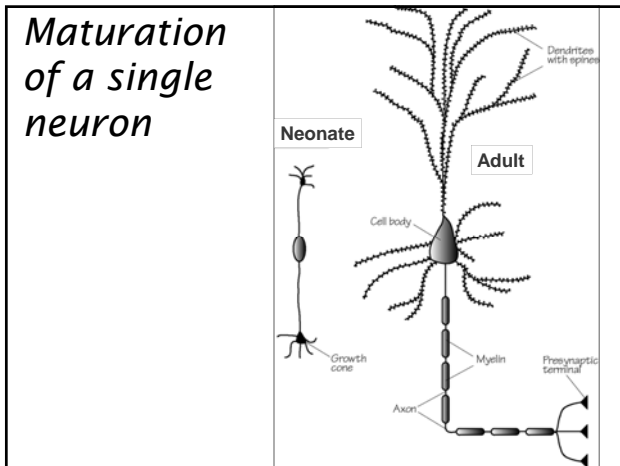


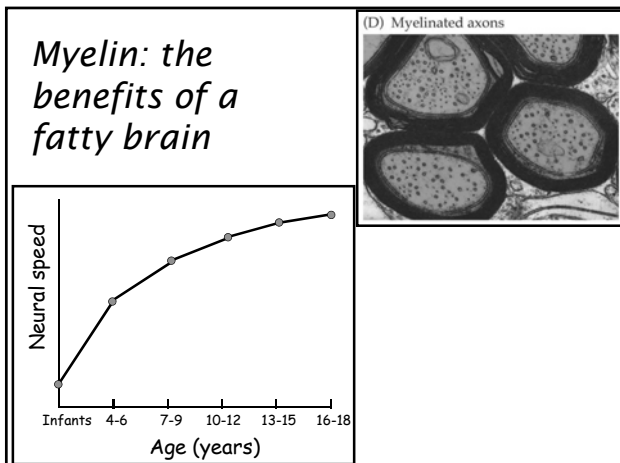
Critical periods

- ◆ Concept originated with early 20th century embryologists
- ◆ Konrad Lorenz popularized in 1930s with his studies of imprinting: permanent attachment established in first day or two after hatching.
- ◆ Well-established for vision and language; good evidence for other sensory systems and social/emotional development.
- ◆ Do they apply to every domain of mental development?









Waves of myelination



Reflexes > Sensory
 > Motor > Emotion >
 Memory > Language
 > Executive
 functions (self-
 control, attention,
 planning, judgment)

Breast is best



- ◆ Breast-fed babies are both healthier and smarter than formula-fed babies:
 - Estimated 2-5 point IQ advantage for term infants; up to 8 points for preterm infants (SES corrected)
- ◆ Advantage due to both the milk...
 - Nutritional factors, e.g. taurine and long-chain polyunsaturated FAs (docosahexanoic acid [DHA] and arachadonic acid)
 - Non-nutritional factors (maternal hormones, enzymes, growth factors, antibodies and immune cells) likely also influence the developing brain
- ◆ ... and parenting differences related to feeding method:
 - Richer sensory/social stimulation with nursing.
 - Higher oxytocin and prolactin levels in nursing mothers may facilitate interactions and lead to better neurodevelopment.
- ◆ AAP recommends breast feeding as exclusive source of milk until 12 months of age.

Balance and motion

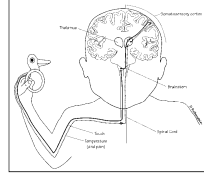


- ◆ Vestibular system matures earliest of all senses.
- ◆ Controls many newborn reflexes.
- ◆ Powerfully linked to motor learning.
- ◆ Self-stimulation common from 6-12 months of age.
- ◆ Rocking, bouncing, swinging, spinning, carrying, and strolling actually good for babies' brains!



Importance of touch

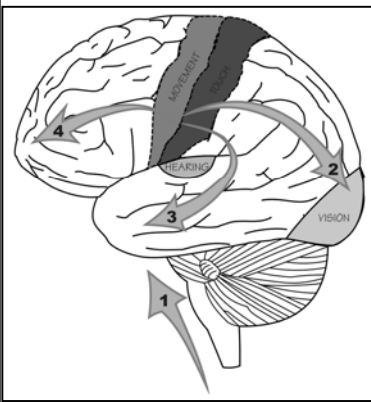
- ◆ Like vision, early touch experience is critical for wiring up sensory cortex.
- ◆ Touch deprivation impairs growth, behavior & immunity.
- ◆ Massage and other tactile interventions have proven beneficial for preterms.
- ◆ "Attachment parenting:" slings & snuglies better than carseats.
- ◆ Problem with current prohibition against touch in schools.



What's wrong with this picture?

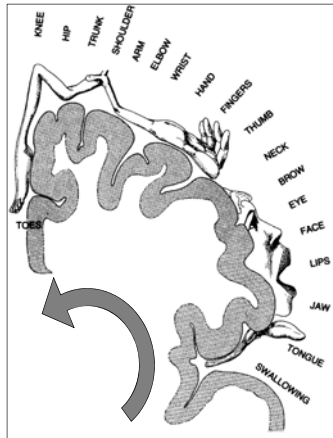
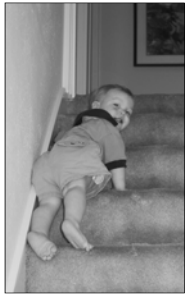


Motor development

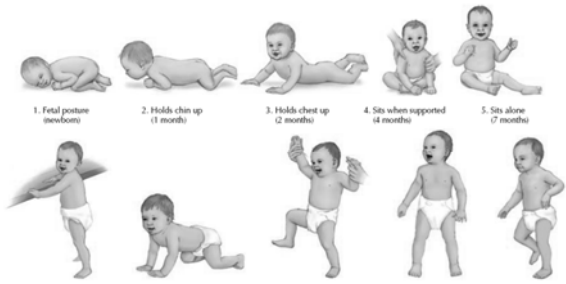


Reflexes > Sensory
> Motor > Emotion >
Memory > Language
> Executive
functions (self-
control, attention,
planning, judgment)

Motor cortex maturation



Gross milestones illustrated



● Figure 3.7. Motor development. Most infants follow an orderly pattern of motor development. Although the order in which children progress is similar, there are large individual differences in the ages at which each ability appears. The ages listed are averages for American children. It is not unusual for many of the skills to appear 1 or 2 months earlier than average or several months later (Frankenberg & Dodd, 1967; Harris & Liebert, 1991). Parents should not be alarmed if a child's behavior differs from the average.

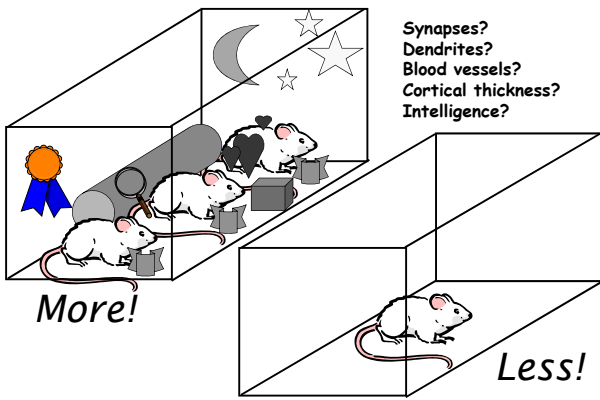
Experience & motor development

- ◆ Motor milestones cannot emerge without a certain amount of programmed neuromuscular maturation.
- ◆ Nonetheless, exercise and other environmental factors are critical for strengthening muscles and selecting the optimal neural pathways for movement:
 - Back-sleeping (recommended for SIDS prevention) modestly delays upper-body milestones, like rolling over and crawling.
 - Baby walkers delay onset of independent sitting and walking.
 - Vestibular stimulation enhances motor reflex and milestone maturation.
- ◆ Voluntary exercise a key component of “environmental enrichment” in studies of animal brain development.

The "exersaucer"



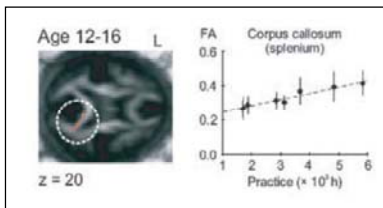
"Enriched" vs. "impoverished"



Activity-dependent myelination

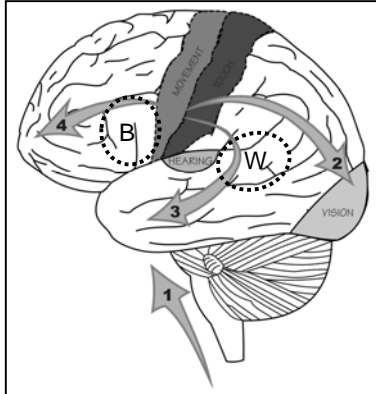
(RD Fields (2005) *Neuroscientist*, 11:528-31)

- ◆ A new concept: plasticity was thought to be limited to gray matter.
- ◆ Repeated activity in an axonal tract (e.g., piano practice) increases functional anisotropy (FA), a measure of tract thickness.
- ◆ It is not yet known whether there is a critical period for this plasticity, but myelination is known to continue to age 30.



Language acquisition

- ◆ To a first approximation, language milestones can be linked to the basic program of brain maturation:
- ◆ Wernicke's area (which is required for receptive language) matures earlier than Broca's area (required for expressive language), in both its degree of myelination and cellular structure.

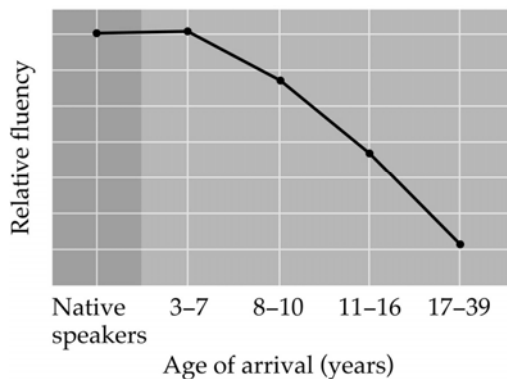


Language milestones

- Receptive milestones always precede expressive milestones and are more diagnostic of language delay.
- Expressive milestones:

Age	Normal expressive ability
1-6 months	Cooing (vowel sounds, "aah," "ooh")
6-9 months	Babbling (consonant-vowel; "ga-ga")
11-14 months	First word (after "mama" or "dada")
22-24 months	Two-word phrases
3-4 years	Three-to-six word sentences
4-5 years	Six-to-eight word sentences

Critical Period for Language



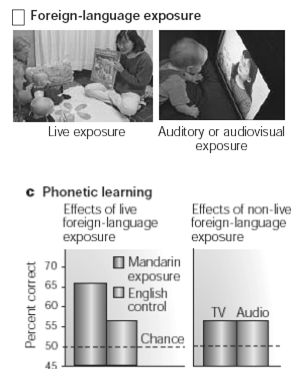
(Johnson & Newport, 1989)

Second language learning

- ◆ Critical period data argue that second-language learning should take place early in life.
- ◆ Bilingualism is common in much of the world.
- ◆ Learning two languages at once does not seriously delay language acquisition or result in any long-lasting language deficits.
- ◆ A second language should be introduced well before school entry, if bilingualism is an important goal of the family or community.
- ◆ At the same time, second-language learning after puberty can still be highly effective and serves important educational goals beyond fluency.

Language must be socially-learned

- ◆ 9-month-olds exposed to Mandarin for just twelve 25-minute sessions showed better discrimination of Mandarin phonemes than babies exposed to the same interaction in English.
- ◆ However, learning required a live, engaged adult. The same teacher on video or audio tape did not improve babies' perception of Mandarin.
- ◆ (Patricia Kuhl et al., 2003).



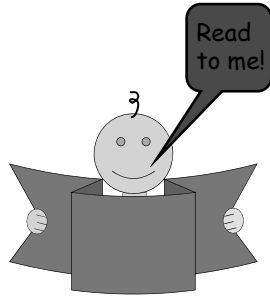
Language In = Language Out

The only "proven" enrichment activity in any cognitive domain is *talking to children*:

- Phoneme learning is shaped by the language and dialect an infant is exposed to.
- Ear infections can affect language acquisition.
- Several studies have found a significant correlation between the number of words addressed by parents or teachers to children and their later verbal IQ.
- Controlled studies indicate that "dialogic reading" accelerates toddlers' verbal development.

How to talk to young children

- ◆ Begin at birth.
- ◆ Parentese helps phonemic learning.
- ◆ More is better, but only if addressed to the child.
- ◆ Repetition and expansion.
- ◆ Listening is equally important.
- ◆ Model, don't correct.



Baby Signing

- ◆ Normally-developing babies gesture before they speak their first words.
- ◆ Gesturing requires less fine motor control than speaking.
- ◆ Study by Acredolo & Goodwyn found that young toddlers explicitly taught to gesture showed more rapid verbal development.
- ◆ Abstract presented in July 2000 reported a 12-point IQ advantage for these children at age 8, but this has yet to be published in a peer-reviewed journal; Hard to rule out a "placebo" effect.
- ◆ At the same time, it is likely that more gestures, like more words, enhance language acquisition.



Why reading to children works

- ◆ Cozy, entertaining, positive emotional context.
- ◆ Broadens the vocabulary we use with children.
- ◆ Pictures make words concrete.
- ◆ Research shows parents do their best language teaching--naming, questioning, listening, repeating & modeling speech--while reading to children.
- ◆ Promotes early literacy, especially if parents also teach ABCs, rhyming, beginning and ending sounds, and other phonemic skills.



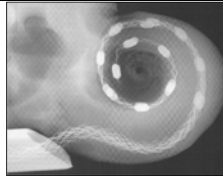
Development of hearing

- ◆ For most children, language is learned aurally, so hearing can limit language and other learning.
- ◆ 1/1000 children born deaf.
- ◆ Congenital deafness typically not diagnosed until 2.5 years of age; may be mistaken for other developmental or behavioral problems.
- ◆ 41 states now mandate universal neonatal hearing screening, using otoacoustic emission (OAE) or auditory brainstem response (ABR) testing.



Cochlear implants

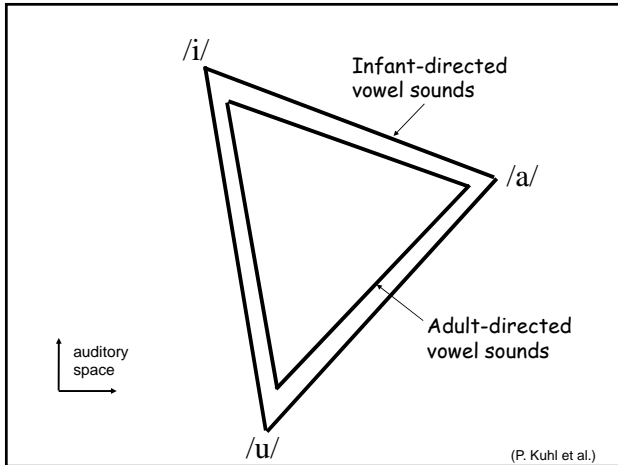
- ◆ Treatment of choice for bilateral deafness.
- ◆ Recent studies confirm critical period for language:
 - Age 6 years is an apparent "cut-off" age for obtaining optimal speech perception and production. Children implanted before 3 years recover enough language for normal school entry. Implantation now routine in 12-month-old infants; experimental in 6-month-olds.
- ◆ Adults born congenitally deaf use their auditory cortex to process vision: cortical competition limits plasticity in older subjects.



American Scientist, September-October, 2004

Phoneme learning

- ◆ Language exposure shapes perception from birth:
 - Paradoxically, young infants can discriminate foreign speech sounds *better* than adults.
 - However, with increased exposure to their native language, babies lose their discrimination of foreign phonemes, while they become better at discriminating native phonemes.
 - Example: adult Japanese are unable to discriminate the English /r/ and /l/ sounds, but young Japanese babies can tell them apart.
- ◆ Strongly implicates some kind of pruning process or synapse selection in higher-order auditory cortex.
- ◆ "Parentese" (universal style of infant-directed speech) exaggerates phoneme separation, helping infants to learn their native language.



Emergent Literacy

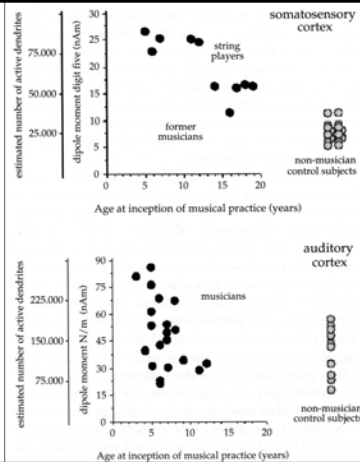
- ◆ Birth-to-school entry a crucial time for acquiring the motivation and skills for independent reading.
- ◆ The more informal reading & writing experiences children have before school entry, the easier their transition to literacy.
- ◆ Pediatrician surveillance of early literacy milestones can be clinically significant for promoting emergent literacy.
- ◆ Girls score ~12% higher on phonological awareness at age 4 to 5.

Music and the developing mind

- ◆ The "Mozart effect" is a short-lasting increase in spatial-temporal IQ demonstrated in *some studies* of young adults. It has never been tested on infants.
- ◆ On the other hand, music promotes memory and is aesthetically pleasing: songs are an excellent teaching tool.
- ◆ Keyboard training may increase spatial-temporal skills.
- ◆ Avoid background music in the classroom.

Critical period for music?

- Perfect pitch occurs rarely (1/10,000) but only among musicians who began their musical training before age 7 (12 at the very oldest).
- Speakers of tonal languages (e.g. Mandarin) produce sounds at nearly perfect pitch, suggesting any infant could learn it.
- Data at right from T. Elbert et al. (2001) shows larger auditory and somatosensory brain areas in musicians trained early.



Limbic system: the emotional brain

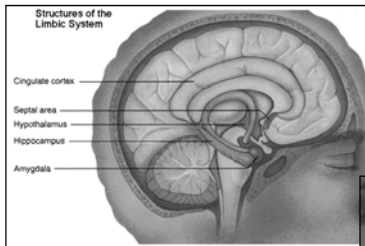


photo courtesy Carrie Nepstad, Erikson Institute

- “Limbic” means border: sits between rational and instinctive parts of brain
- Cortical areas develop through relationships and social interaction.

Social-emotional milestones

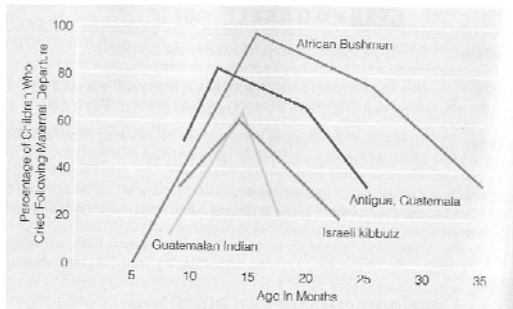
- Newborns are instinctively social: most facial expressions, crying, imitation, and autonomic emotional responses are present at or near birth, reflecting the relative maturity of subcortical limbic structures.
 - Social smiling begins at ~ 44 weeks post-conceptual age.
 - “Protoconversation” from 2 months (cooing with partner)
 - Joint attention from 3 months (follows adults’ visual focus)
- Attachment behaviors (*separation anxiety* and *stranger anxiety*) emerge around 6 months of age, and grow increasingly intense to 18 months. “Strange Situation” measures attachment security.
- Self-control and self-awareness begin ~ 18 months
- Peer interactions: parallel play to age 3, cooperative play by age 4

Imitation

- Two studies c. 1980 showed that newborns can mimic facial expressions of an adult model (Meltzoff and Moore; Field et al.).
- Infants later diagnosed as autistic imitate less than normally-developing babies.
- Imitation a very potent form of learning that shows long-term memory and makes the most of our highly social nature.
- "Mirror neurons" in premotor cortex thought to begin functioning ~ 8 mo. of age.

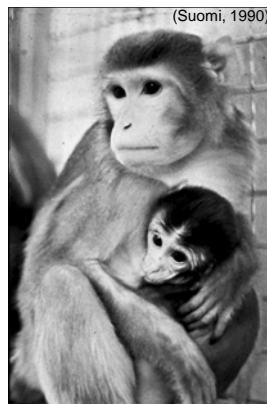


Separation anxiety

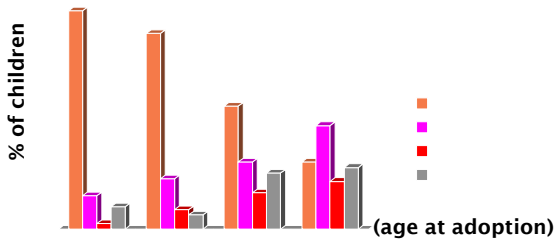


Role of experience

- Maternal deprivation profoundly affects prefrontal cortex, neurohormones, and behavioral development.
- In rhesus monkeys, the critical period for normal social development extends from birth to 6 months.
- Best data for humans come from recent cohort of Romanian orphans, adopted into middle-class European and N. American homes in 1989:
- Critical period for humans from birth to about 3 years.



Romanian adoptees at age 6



- ◆ Domains include: attachment disorders, ADHD, emotional difficulties, autistic features, cognitive impairment, peer difficulties, conduct problems.
- ◆ Michael Rutter et al., *Br. J. Psychiatry*, 179:97 (2001)

Frontal lobe: the brain's "executive"



Reflexes > Sensory
 > Motor > Emotion >
 Memory > Language
 > Executive
 functions (self-
 control, attention,
 planning, judgment)

Attention = inhibition

- ◆ One of the major functions of the frontal lobe is to inhibit inappropriate movements, thoughts & behaviors.
- ◆ Inhibition is necessary for any task requiring focused attention.
- ◆ Likely underlying deficit in ADHD (Russell Barkley).
- ◆ Inhibitory control develops VERY SLOWLY:
 - young infants are in near constant motion
 - preschoolers get more active the more tired they are
 - elementary school children can't sit still for long periods
 - many teenagers continue to have poor impulse control



Inhibitory control: Stroop tests

red
green

Tools of the Mind

**Preschool Program Improves
Cognitive Control**

Adole Diamond,^{1*} W. Steven Barnett,² Jessica Thomas,² Sarah Munro¹

SCIENCE VOL 318 30 NOVEMBER 2007



"Buddy reading." Two preschoolers engaged in Tools activity. The ear line-drawing held by one guides her attention (2).

Early learning & the brain

- ◆ Emotions and relationships come first!
- ◆ Children learn through repeated, hands-on, verbal & multi-sensory experiences.
- ◆ Early intervention appears beneficial for all developmental disorders (autism, dyslexia, Down syndrome, cerebral palsy).
- ◆ High quality education must begin earlier.
