




Fetal and early learning – relevance for future outcomes

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Cortical development

- Activity-dependent development
 - Cortical regions associated with sensory functions develop intrinsically.
 - Associated with slow-wave neural activity (Vanhatalo & Kaila, 2006)
- Stimulus-driven development
 - Sensory input drives cortical development and structure.
 - E.g. formation of columnar organization in the cortex, tonotopic organization of the auditory cortex etc.

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Cortical development

- Activity-driven development results in the species-specific neural architecture.
 - Preparing the brain for future input.
- Stimulus-driven development shapes the fetal brain to process stimuli it is exposed to.

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Part 1: Neural basis of fetal learning

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How do fetuses perceive and process stimuli?

- Especially sounds are probably perceived in a multimodal fashion
 - when the mother speaks, the diaphragm and abdominal muscles move, which may also be perceived by the fetus.
- Do different sensory modalities in the human nervous system develop separately?
- Is the young nervous system is inherently multisensory and different senses segregate later in development?

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Why is multimodality important?

- When fetus or infant is not familiar with the stimuli it is exposed to, multimodal stimulation may make certain sound features more salient?
 - Easier to focus the attention on these features.
- Intersensory redundancy hypothesis (James J Gibson, 1966; e.g. Bahrick et al., 2004).
- Phillips-Silver and Trainor (2005): bouncing babies

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Is fetal learning just habituation?

- We cannot measure learning on-line, we have to infer learning from the outcomes.
- Studies conducted using exposure could thus result from simple habituation.
- However, the effects of learning are seen as preference of one stimulus over another or as a heightened neural or behavioral response to a familiar stimulus.
 - Habituation would instead be seen as a reduced response.

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Multimodality?

- In monkeys, multimodality may develop later and more lower brain structures do not seem to have multimodal properties (for a review, see Wallace, 2004).
- In contrast, in bird embryos, learning of the maternal call is improved by multimodal fetal exposure (Jaime et al., 2010).
- Regardless, the developing nervous system is highly plastic (e.g., Mao et al., 2011; Mao & Pallas, 2013).

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For more details:

- Partanen & Virtala, 2017, Cambridge encyclopedia of Child Development

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Fetal behavioral states

- Early learning is probably not only related to characteristics of stimulation, but also to the state of the fetus.
- The latency of fetal neural responses to sounds shortened when the fetus was in a more active state (Kiefer-Schmidt et al., 2013).
- Some studies in infants show that neural responses differ on sleep stage (Friederici et al., 2002).
 - But not found in all studies (e.g. Martynova et al., 2003)

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Part 2: Long-term effects of fetal and early learning

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Additional fetal exposure has no shown long-term benefits

- Partanen et al.: neural effects for four months, no follow-up.
- For a review, see Moon et al., 2000.
- Does learning during the fetal period generalize?
 - Probably yes, to some extent: infants exposed to a certain melody, recognize that melody even when it is transposed (Plantinga & Trainor, 2005).

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Forming habits: singing

- Our projects in Sweden suggest that inspiring parents to sing with preterm infants results in especially fathers taking a larger role in infant care.

Activity	Group	Singing group (Hours)	Silent group (Hours)
Skin-to-skin contact	Mothers	~120	~110
	Fathers	~15	~5
Singing	Mothers	~20	~15
	Fathers	~12	~2

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Fetal stimulation as "enriched environment"

- Animals may show benefits (i.e., improved ability to navigate a maze in rats; Aoun et al., 2005) from enriched auditory environment during pregnancy.
- Human fetuses of healthy mothers are normally exposed to very rich environment.
- Infants whose mothers are deaf develop a spoken language (see Lillo-Martin et al., 2014, for a review).
 - No disadvantage from a lack of prenatal exposure either?

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Why singing and music?

- Parentese is similar to singing and exaggerated cues in parentese aid infants in their discrimination of words.
- Also infant-directed singing and caregiver-mediated musical play capture the infants' attention, and help them to modulate their arousal and to synchronize with their caregivers, promoting parental sensitivity.
 - This positively correlates with attachment security, resulting in beneficial socio-emotional outcomes.

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Fetal stimulation as forming habits and improving attachment

- parents interested in the well-being of their future child may be eager to try to expose their children to additional prenatal stimulation (Moon & Fifer, 2000).
 - The interest of the well-being of the child already prior to birth improve attachment and have cognitive benefits (Moss & St-Laurent, 2001).
- In addition, forming habits that will improve development may have long-term effects.

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Home environment and development

- Informal musical activities seem generally beneficial for language outcomes in early development.
- In contrast, 'screen time' (playing with tablets, mobile phones, etc.) hinder it.
- Most likely not a result of 'screen time' as such, but due to parental style.

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Home environment and long-term outcomes

- Singing with the infant and reading to the infant generally improve language performance. Especially musical play school is highly effective in improving future outcomes.

The more kids attended music play school

Response	Mean
No	~105
Yes	~115

Legend for Box Plot:

- musiikkileikkikoulu harrastamattomat (white box)
- musiikkileikkikoulu harrastaneet (grey box)

Y-axis: Balesin III indeksi (80-130)

X-axis: kielellinen indeksi, kognitiivinen indeksi

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To provide benefits, what makes a good intervention?

- Lasting effects only if the parents can select the music and use music in parenting in a way best suited for them.
- Empowering and inspiring parents to include music in parent-infant interaction may be most beneficial:
 - Supports attachment.
 - Allows motivated parents to direct the infant's attention to music on a regular basis.
 - Alleviates caregiver stress.

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Parental style and interaction

- Capturing the attention may be the key!
- Intersensory redundancy hypothesis!
 - Change in several sensory modalities focuses attention and drives interaction.
- Vygotsky: in a social setting the caregiver can provide optimal challenges.
- At least in preterms, maternal sensitivity is positively associated with language development.

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Social interaction

- Kuhl et al., 2004: during the first year of life, learning a new language occurs only in social interaction and passive exposure has little to no effect.
- How to direct attention: a person teaching 'live' can interactively get the infant to direct its' gaze to what is being taught; the more often the gaze is directed to the relevant items to be learned, better the learning outcomes are (Conboy & Kuhl, 2010; Conboy ym., 2008).

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