The development of musical abilities

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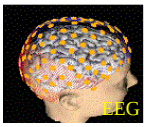
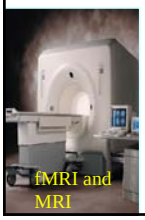
Methods for developmental studies

PET is not often used in children


EEG


Optical imaging


fMRI and MRI

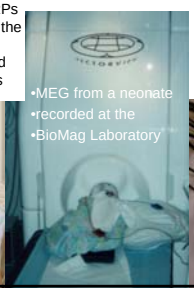

MEG


Child/infant MEG


Fetal MEG

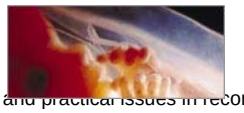
The neonate as a participant

Auditory ERPs recorded at the Hospital for Children and Adolescents


•MEG from a neonate
•recorded at the
•BioMag Laboratory

Optical imaging of a neonate with the instrument developed by FIIP

Recording from the fetus



Technical and practical issues in recording
Cardiac and other noise cancellation in data analysis
Interpreting and statistical testing of results


BioMag Laboratory

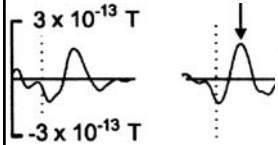
How to study the cognitive capabilities of fetuses

- Animal models
- Studies after birth, related to fetal life like exposure to music etc.
- Prematurely born infants are similar to fetuses for a short period after birth. Thereafter, their development starts to differ.
- During the fetal period, movement, heart rate and brain responses can be measured.

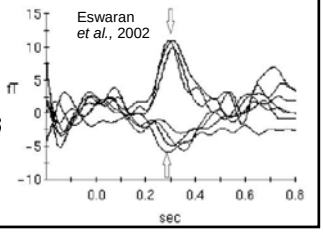
Sound onset detection in the fetus

- Several studies have demonstrated onset-responses in fetuses around 150 – 300 ms
- Earliest detection at 29 w GA

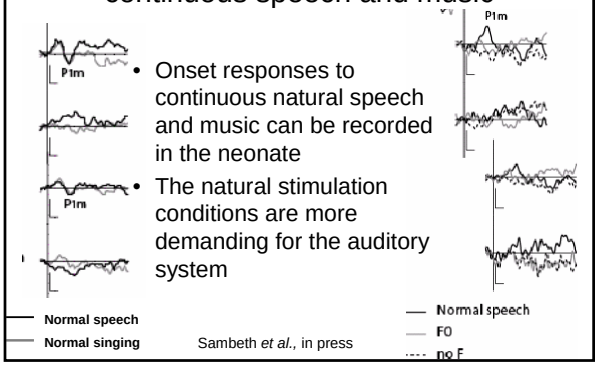
Lengle *et al.*, 2001



Eswaran *et al.*, 2002



Sound onsets detected by neonates in continuous speech and music



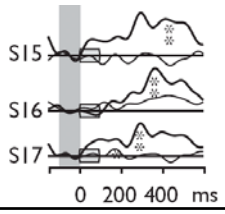
- Onset responses to continuous natural speech and music can be recorded in the neonate
- The natural stimulation conditions are more demanding for the auditory system

Sambeth *et al.,* in press

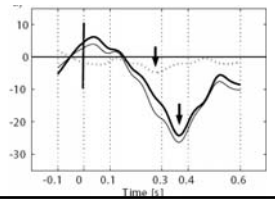
Comparison process in fetus

- Two studies report MMN(m) in fetuses; both to large changes of sound frequency

Huotilainen *et al.,* 2005

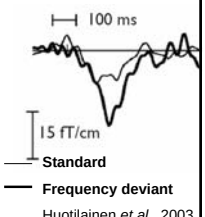


Draganova *et al.,* 2005

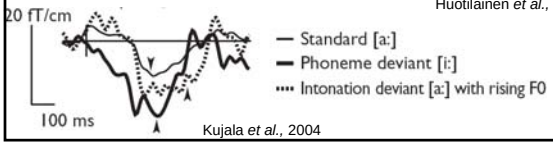


Comparison process in neonate

- MMN for changes in basic features is reported in the neonate by several groups
- It may vary in latency and polarity
- MMNm in neonates



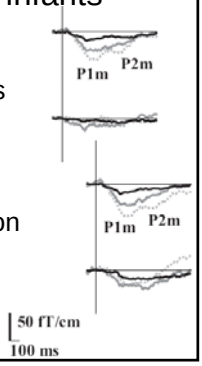
Huotilainen *et al.,* 2003



Kujala *et al.,* 2004

Responses to frequency deviants and novel sounds in infants

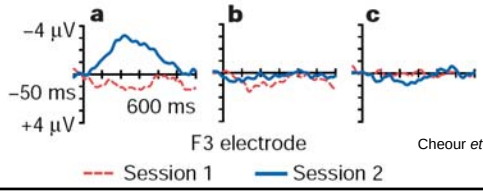
- Responses to ”novel” sounds differ from those to ”deviant” sounds
- Is this a means to study involuntary attention-allocation in neonates?



Sambeth *et al.,* 2005

Speech-sounds learned by sleeping newborns

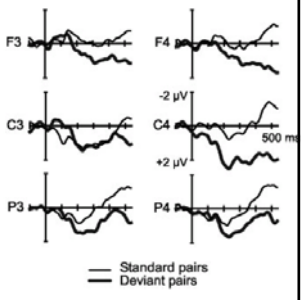
- During sleep, infants were trained with
  a) /y/ vs /y/i/ contrast
  b) nothing
  c) another vowel contrast
- Prior to and after training, MMN to /y/ vs /y/i/ contrast was recorded



Cheour *et al.,* 2002

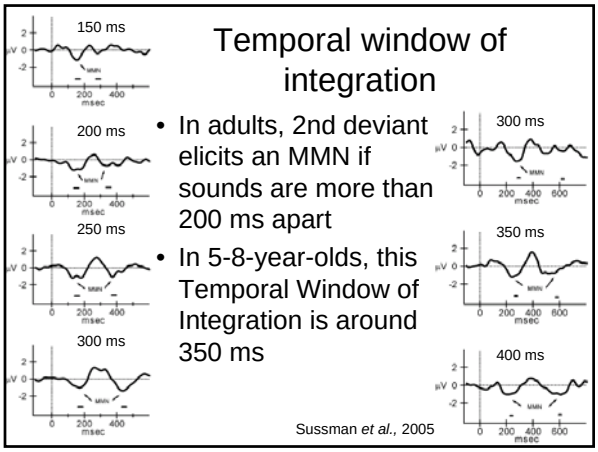
Primitive intelligence in the neonate

- The neonatal brain automatically extracted a complex rule in the sound stream
- Rule: ”the second part of the tone is always higher in pitch than the first”
- Breaking the rule resulted in MMN



Carral *et al.,* EJN 2005

Temporal window of integration

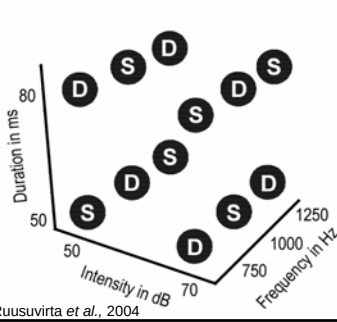


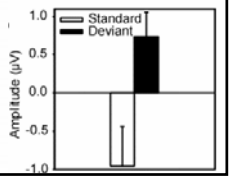
- In adults, 2nd deviant elicits an MMN if sounds are more than 200 ms apart
- In 5-8-year-olds, this Temporal Window of Integration is around 350 ms

Sussman *et al.,* 2005

Feature-binding in the neonate

- In order to detect deviants, 3 features need to be binded and the combinations stored in memory

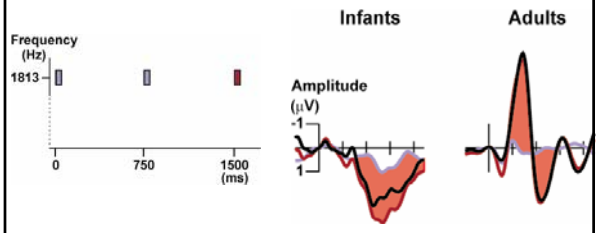




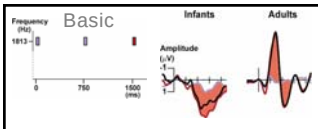
Ruusuvirta *et al.,* 2004

Stream segregation in neonates

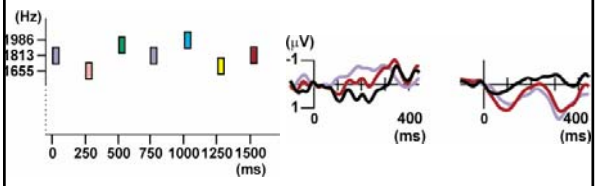
Basic condition



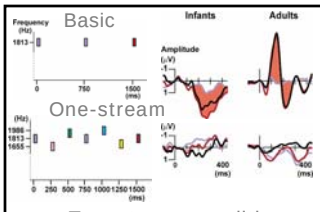
Stream segregation in neonates



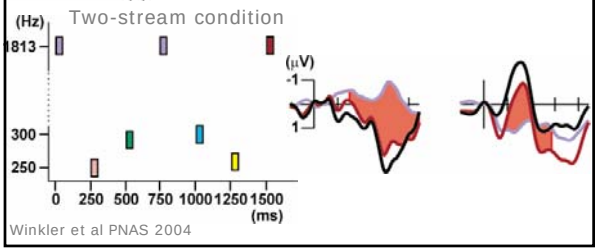
One-stream condition



Stream segregation in neonates

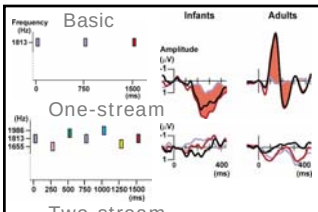


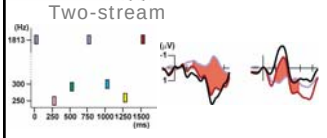
Two-stream condition



Winkler et al PNAS 2004

Stream segregation in neonates





Winkler et al PNAS 2004

Streaming is an important skill of the auditory system.

It is required for separating sound sources and maintaining a coherent percept of a stream.

Without streaming, each intervening sound would break the predictability and memory trace of a sound stream.

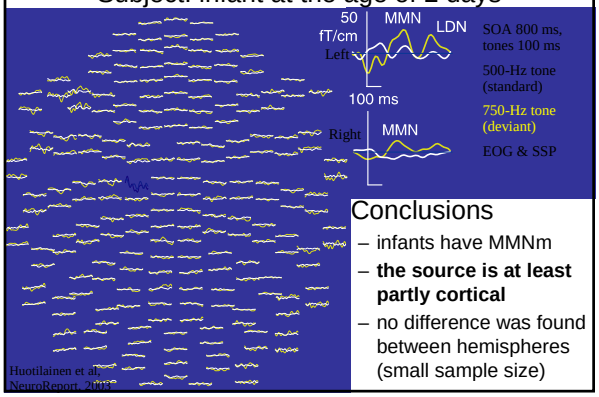
Fetal learning

– Fetal learning has been shown with behavioural methods at birth
  - advancement of motor development in monozygotic twins due to somatosensory stimulation in the uterus
  - preference for fragrants of mother's diet
  - clear recognition of mother's voice, repeated musical pieces, and phrases read before birth

Two ongoing studies related to fetal learning

1. MEG studies: on-line learning recorded during the stimulus processing and presentation of new and learned material
   - First steps: MMNm in neonates and fetuses
2. Neonatal studies: "training" of auditory material during the fetal period, but recording right after birth
   - First steps: responses to learned speech and music

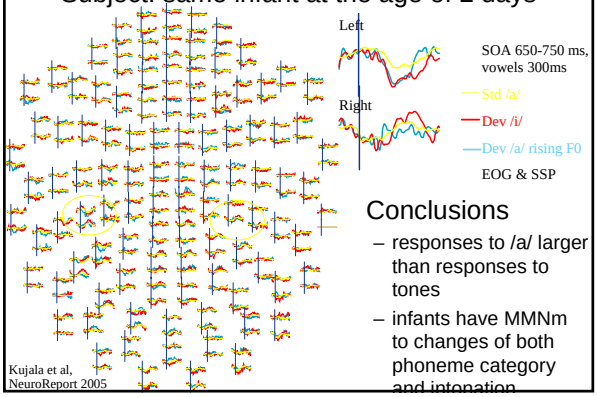
MMNm to frequency change
Subject: infant at the age of 2 days



Huotilainen et al. NeuroReport, 2005

Conclusions
- infants have MMNm
- **the source is at least partly cortical**
- no difference was found between hemispheres (small sample size)

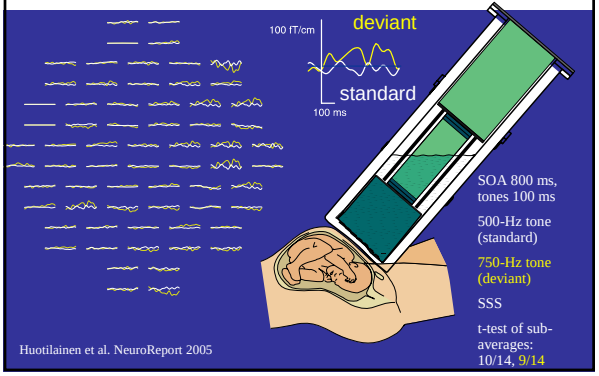
MMNm to changes in phonemes
Subject: same infant at the age of 2 days



Kujala et al, NeuroReport 2005

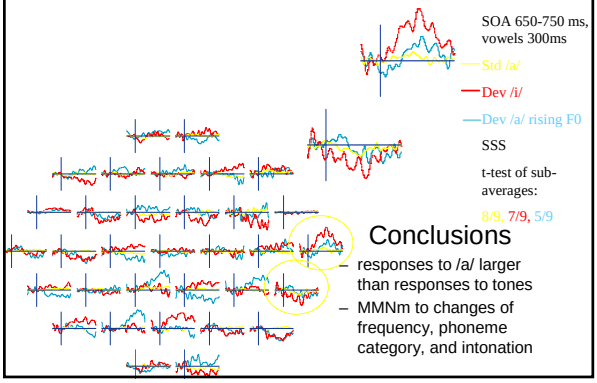
Conclusions
- responses to /a/ larger than responses to tones
- infants have MMNm to changes of both phoneme category and intonation

MMNm to frequency change
Subject: same person, age 36 weeks GA



Huotilainen et al. NeuroReport 2005

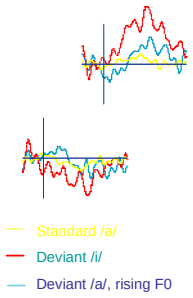
MMNm to changes in phonemes
Subject: same fetus, age 36 weeks GA



Conclusions
- responses to /a/ larger than responses to tones
- MMNm to changes of frequency, phoneme category, and intonation

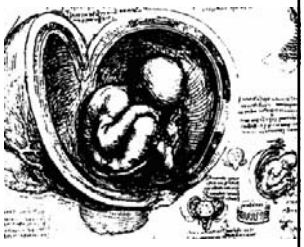
Change of phoneme or change of prosody

- The fetus can detect the change of phoneme category: at least part of formant information is transmitted.
- The fetus can detect the change in intonation: lower part of the spectrum is transmitted well.



Repeating speech and music to the fetus

We had 29 women with uncomplicated singleton pregnancies volunteering to play a tape of 15 minutes after week 29 GA until birth 5 times/week.



Results from fetal language learning studies

- Preliminary data analysis seems to suggest a difference between those neonates, who had learned the Thai language phrases, and those who had never heard them before.

Results from fetal music learning studies

- Preliminary data analysis seems to suggest that there is a response to the ”mistakes” in the musical pieces in both groups.

Fetal learning

- Fetal learning differs from later learning
  - cortex is not mature enough to store ”memories”
  - hippocampus is not mature yet
  - lower brain areas are active
- Fetal learning is a way to adapt to the environment
  - adaptation to the acoustic surroundings
  - recognition and attention towards speech of familiar people

New information on neonatal capabilities

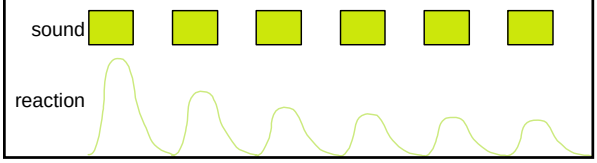
- The auditory skills of neonates are higher than previously thought
- Binding is needed in order to combine continuous acoustic features into coherent sound sources
- Streaming is required for selecting and attending to a sound source

Fetal hearing

- Startle, head movement, limb and eye lid movement, changes of pulse to sounds after 20 weeks of gestational age (wGA).
- At 24 wGA: brain stem, middle latency, late cortical auditory responses: information travels to the brain. At 30 wGA: less individual variation in the responses.

Habituation is a simple form of memory

- Combined sound-tactile stimulus: fetus shows habituation after 10 stimuli. Habituation is faster the next time, but not after 3-4 days.



What does an infant want to hear?

- Sounds resebling uteral sounds like heartbeat and noise
  - Already in the 1960's (Salk et al., Murooka et al.)
  - Still used in the neonatal wards
- Familiar sounds from the fetal period
- Speech and speechlike sounds

An infant is interested in speech sounds

Overview of fetal cognitive skills

- From the outside world, the fetus perceives sounds, smells/fragrances and posture/movement information.
- The fetus learns from this information.
- The "goal" of this learning is to adapt to the future environment after birth. Learning directs future attention, which in turn enhances learning of the attended stimuli (speech).

A baby prepares herself to birth by acquiring information from the outside world

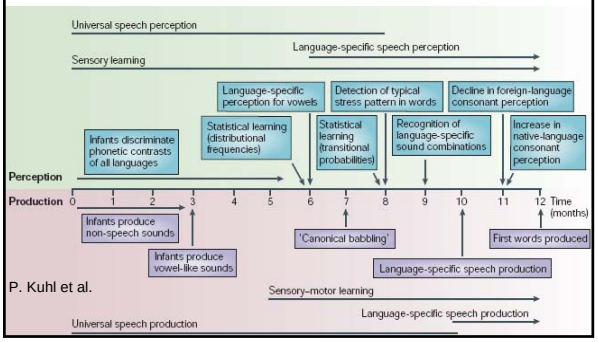
- After birth, the infant prefers smells and sounds familiar from the fetal period. She/he uses them to identify her/his family members and familiar situations/places.

- Music and speech related to mother's positive emotions during the fetal period are of special importance to the infant after birth. Positive memories are strongest.

Music in the infant's life

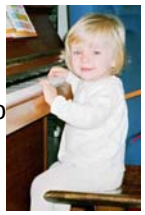
- The swinging movement from the fetal period is related to mother's walking and is a familiar "musical" stimulus
- Motherese (enhancing prosodic features in speech) resembles music

Language development up to age 12 months



Development of musical skills

- An infant recognizes melodies, rhythms, pitch changes, etc.
- 6 months: testing the limits of one's voice
- 1 year: strong body movement to music
- After 5 years: ability to produce accurate pitch in voice



Infant's perceptive skills

- The perception of frequency, timing, and timbre is finer than what is required for musical purposes.
- Perceptual grouping works similarly as in adults (can follow one instrument when other instruments are playing etc.).

Relational processing of pitch and duration in infancy

- Infants recognize a melody in transposition
- Especially clear is the skill to compare pitch contour
- Infants recognize a melody with an altered tempo
- Both of these skills require relational processing of frequency and duration or time

Detecting changes in intervals

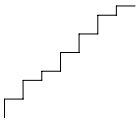
- Infants, children and adults detect changes in intervals best in the context of small integer ratios
  - perfect 5th = 7 semitones = 3:2
  - octave = 12 semitones = 2:1
  - perfect 4th = 5 semitones = 4:3
  - Compare to tritonus = 6 semitones = 45:32

Detecting changes in intervals

- Preference to small integer ratios in intervals is probably due to physiology of the auditory system
- Infants are more attentive and exhibit more positive affect when listening to consonant music than to music with many dissonant intervals

Scale structure

- Infants prefer scales with unequal steps
- Infants do not prefer Western musical scale over other artificial scales with unequal steps
- This may also be due to the physiology of the auditory system



Temporal processing

- Infants, like children and adults, prefer tone durations with binary relations
  - 1/1, 1/2 , 1/4, 1/8, 1/16 etc
- Melodic processing is more accurate if tone durations have binary relations

Hemispheric specialization

- Infants have right-ear advantage for speech and left-ear advantage for music
  Bertoncini et al., 1989, Best et al., 1982
- 8-month-old infants show left-ear advantage for contour processing and right-ear advantage for interval processing
  Balaban et al., 1998

Maternal music and speech

- Caregivers in all cultures sing to infants
- Caregivers also speak to infants in ”motherese”, a style of speaking that uses a lot of repetition, slow tempo, high pitch, and large pitch variations
- Singing and speaking style to infants has strong similarities

Optimizing mood

- Maternal singing (and maternal speech to a lesser degree) optimize the infant’s mood in wakefulness
  - Drowsy, low-activity state is drifted towards attentive state
  - Anxious state is drifted towards steady, calm and attentive state
- Maternal singing of lullabies brings the baby to ”trance-like” state and towards sleep

Optimizing language learning

- Some researchers claim that language learning is facilitated by mother's singing and maternal speech

Questions

- Are musicians talented at birth and drawn to music because of their talent? Or do the become so talented because they get so much stimulation?
- What does it mean that the brain responses show an effect? Can we assume conscious perception? What is the meaning of the sub-conscious?
- Similarities and differences between speech and music