Voice and Emotion Processing in the Human Neonatal Brain

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Aug. 2, 2013

Are Humans Innately Social?

lessons from **NEWBORNS**

How Well Can Newborns See and Hear?

- At birth, babies sees only in black and white and shades of gray.
- Newborn babies can hear fairly well.

- Voices, like faces, convey a large amount of socially relevant information about the people around us.
- One can infer the emotional state (happy, sad angry, etc) from a voice even in an unfamiliar language (Scherer et al. 2001)

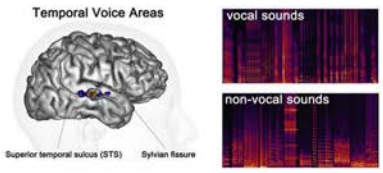
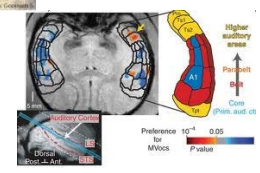


Figure 1. Temporal Voice Areas in the Adult Brain
The contrast of cerebral activity measured in the adult brain by functional magnetic resonance imaging (fMRI) in response to auditory stimulation with vocal versus non-vocal sounds (stimuli available at http://vnl.psy.gla.ac.uk) highlights voice selective TVA with greater activity in response to the vocal sounds. The TVA (shown here in an individual young adult subject) are mostly located along the middle and anterior parts of the superior temporal sulcus (STS) bilaterally.

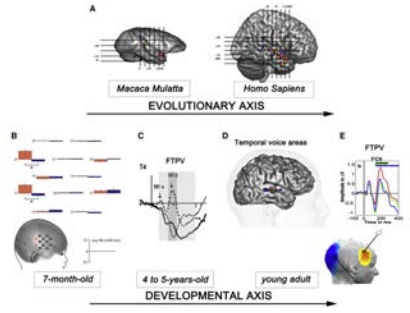
Belin et al. (2000) *Nature*

A voice region in the monkey brain

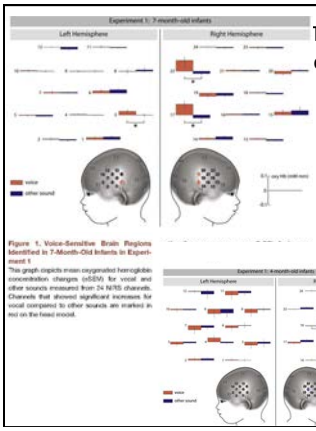
- Petkov et al. (2008)



Phylogeny and Ontogeny of Cerebral Voice Processing

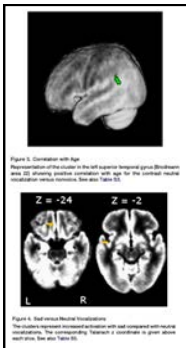


Belin & Grosbras. (2010) *Neuron*



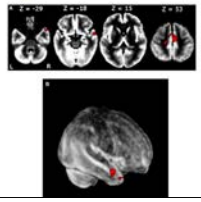
The Developmental Origin of Voice Processing in the Human Brain

- Grossman et al. (2010))
- 7, not 4 month-olds
- NIRS (n= 16)



Early Specialization for Voice and Emotion Processing in the Infant Brain

- Blasi et al. (2011)
- 3- to 7-month-olds, sleeping
- fMRI (n= 20)



Are Humans Innately Social?

Voice

Mismatch Negativity

- At birth, babies sees only in black and white and shades of gray.
- Newborn babies can hear fairly well.

Validation for Emotional Voices

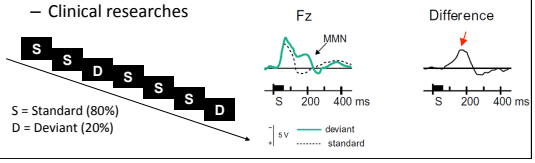
- "dada": meaningless syllables
- Neutral, happy, angry, fearful, sad, disgusted
- Within each set of emotional syllables, one female and one male speakers produced "dada" more than ten times
- Emotional syllables were edited to become equally long (550 ms) and loud (min: 59 dB; max: 62 dB)
- Each set was rated for emotionality by 120 listeners
- Listeners classified each stimulus with a 5-point scale from 'extremely angry', to 'not angry at all'.
- Emotional syllables that were consistently identified as 'extremely emotional'
- Neutral syllables rated as the most emotionless were selected as the stimuli

Acoustic Control: Nonvocal Sounds

- Praat (Boersma, 2001) and Matlab software
- Simple tones: spectral controid (fn)
- Complex tones: fundamental frequency (f0)
- Extracted and multiplied
- Temporal features: the same temporal envelopes
- Spectral features: fn vs. f0
- Length: 550 ms
- Loudness: 59 ~ 62 dB

Mismatch Negativity (MMN)/ Mismatch Response (MMR)

- Näätänen et al. (1978)
  - Event-related potential (ERP) component as an index of automatically auditory discrimination
  - **Mismatch response (MMR)**: the equivalent of MMN in infancy (Friederici et al., 2002)
  - Advantages: attention- and task-independent
  - Auditory passive-oddball paradigm
  - Clinical researches



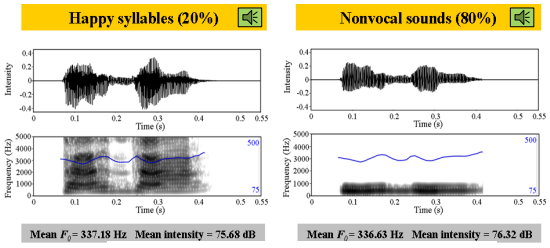
Hypothesis on MMR

- **If newborns are sensitive to voices, they are born with the ability to distinguish voices from sounds.**
- Then, newborns can distinguish emotions (happy, fear, etc.) from voices.
- However, the greater response to affective (happy and angry) compared to neutral voices could reflect the processing of many acoustical differences between these categories (e.g., f0 range) without implying emotional processing (Belin & Grosbras., 2010).
- The responses elicited by affective voices should differ from those by their acoustic controls (selectivity).

Exp. 1: Are Newborns Sensitive to Voices?

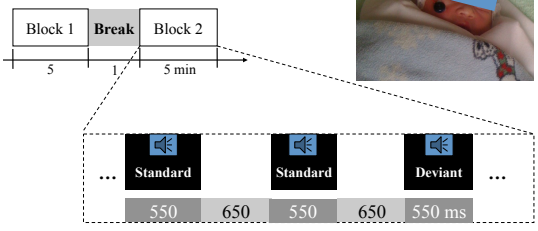
Newborn Babies (N = 25, 15 boys)	*M*	*SD*	Range
Gestational age (week)	38.8	4.5	36~40
Birth weight (gw)	3119	307	2755~3890
Age (day)	1.6	1.1	0~5

- Newborns paid more attention to happy than other negative or neutral voices (Mastropieri & Turkewitz, 1999).
- Young infants would prefer to listen to positive than to negative emotional voices (Vaish & Grossmann, 2008).

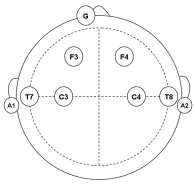


Nonvocal sounds retained the mean intensity, F_0 contour, duration, voice-onset time of the emotional syllables, and low-pass filtered the signal above 300 Hz.

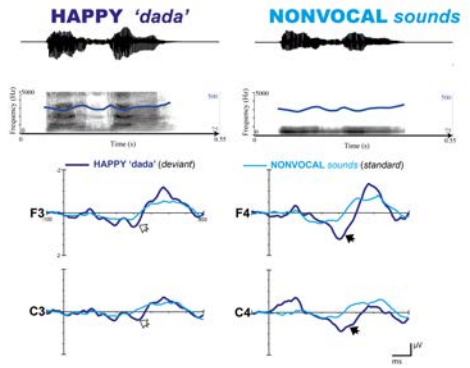
Auditory Oddball Paradigm



Data Acquisition



- **EEG Recording and Parameters**
  - Sampling rate: 250 Hz
  - Band-pass filtering: 0.1-100 Hz
  - Reference: A2
- **ERP Data Analysis**
  - Re-reference: (A1 + A2) / 2
  - Block rejection
  - Epoching: -100 ~ 800 ms
  - Baseline correction
  - Band-pass filtering: 1-15 Hz
  - Artifact rejection: ± 150 μV
  - Baseline correction
  - Average
  - **Subtraction: MMR = Deviant ERP – Standard ERP**



Cheng et al. (2012) *J Cogn Neurosci.* 24(6): 1411-9.

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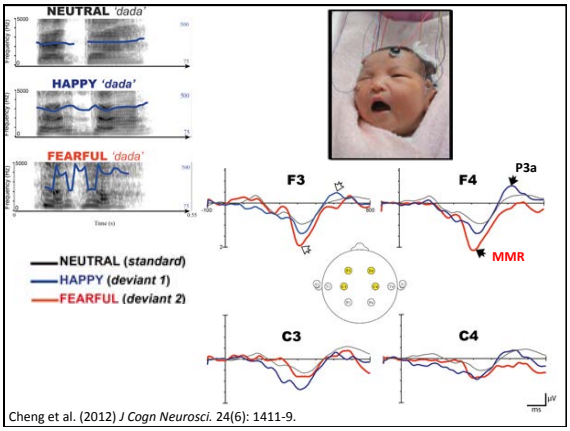
- The responses elicited by affective voices should differ from those by their acoustic controls (selectivity).

Exp. 2: Can Newborns Distinguish Emotions from Voices?

Newborn Babies (N = 43, 23 boys)	*M*	*SD*	Range
Gestational age (week)	38.5	1.1	37~40
Birth weight (gw)	3195	310	2600~3890
Age (day)	1.6	1.2	0~5



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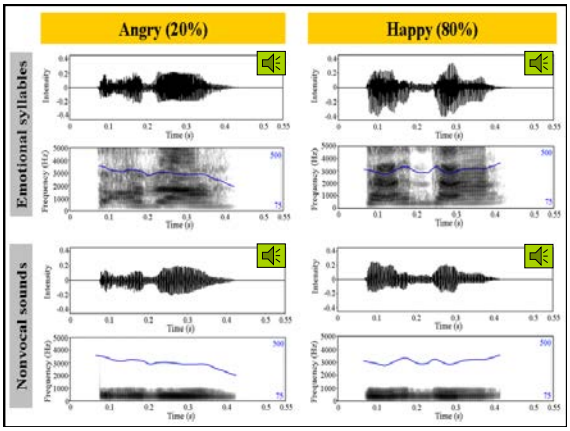
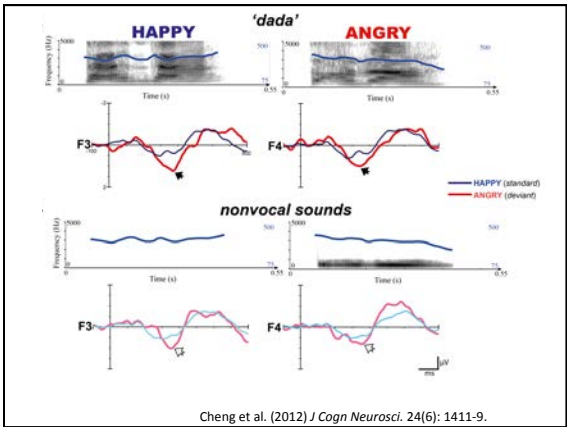
Exp. 3: Is the Affective Discrimination driven by Voice Processing *Per Se*?

Newborn Babies (N = 30, 19 boys)	*M*	*SD*	Range
Gestational age (week)	38.5	1.1	36~40
Birth weight (gw)	3195	310	2600~3890
Age (day)	1.6	1.2	0~5





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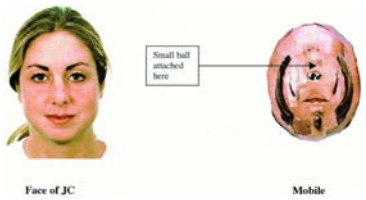
MMR findings in Newborns

- Happy syllables *vs*. Nonvocal sounds ➔ Humans at birth possess voice sensitivities.
- Happy *vs*. Fearful *vs*. Neutral syllables ➔ Affective prosody discrimination over the first days of life.
- Happy *vs*. Angry syllables, NOT Happy-derived *vs*. Angry-derived nonvocal sounds ➔ Affective voice discrimination is selectively driven by voice processing *per se*.
- No gender differences

Cheng et al. (2012) J Cogn Neurosci. 24(6): 1411-9.

Sex differences in human neonatal social perception

Connellan, Baron-Cohen, Wheelwright, et al. (2000)



Humans are Innately Social !

The emergence and maturation of cerebral specialization for human voice emerges in the first days of life, enabling newborn to be socially responsive.

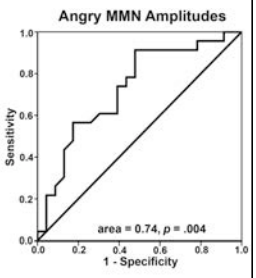
Emotional MMR/MMN

- Can be a biomarker of normal cerebral voice development (N > 100)
- May be crucial in assessing the infants at risk for neurodevelopmental disorders with social deficits, such as autism spectrum disorders (ASD).

Future Applications of eMMN

Emotional MMN in Adults with ASD (n = 24)

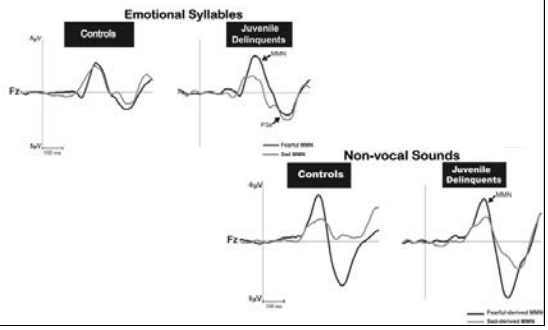
- Receiver operator characteristic (ROC) analysis indicated **angry MMN** amplitudes with a sensitivity of 95.8% and a specificity of 91.7 % for diagnosing ASD.
- Weaker angry MMN coupled with more autistic traits (Autism Quotient, r = 0.35).



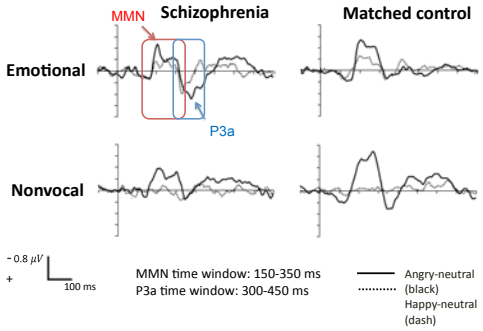
Fan & Cheng (*submitted*)

Atypical MMN to distressful voices associated with conduct disorder symptoms

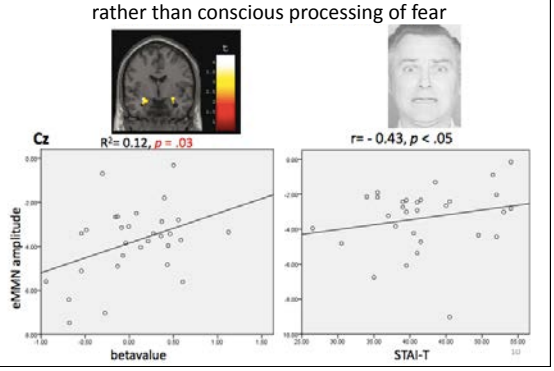
Hung, Ahveninen, & Cheng (2013) J Child Psy Psy Epub ahead of Print



Atypical eMMN in Chronic Schizophrenia

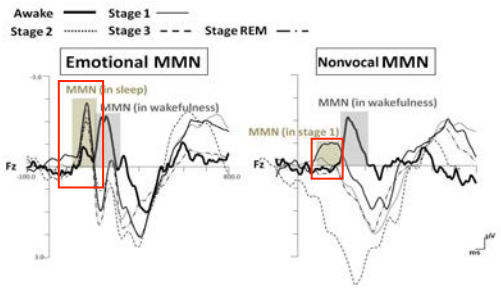


eMMN predicts amygdala reactivity to non-conscious rather than conscious processing of fear



MMN in Sleeping Brain

Time window: 200-280 ms in wakefulness
120-200 ms in sleep



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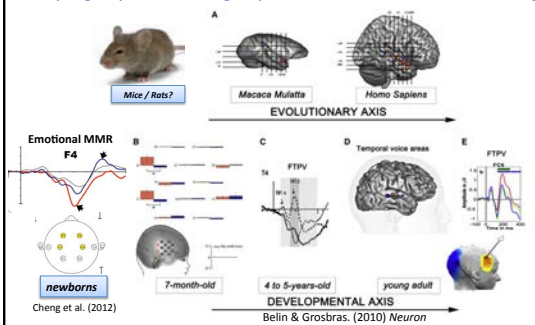
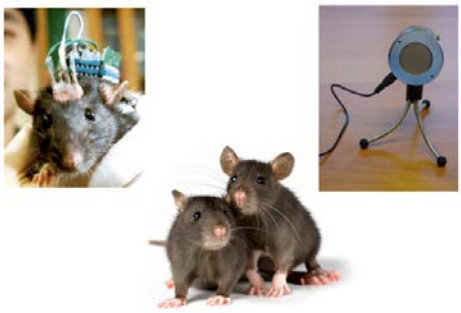


Cheng et al. (2012)

Belin & Grosbras. (2010) *Neuron*

eMMN in rats and mice



ACKNOWLEDGEMENTS

Yang-Teng Fan (范揚騰)
Chen-Yi Chen (陳濬毅)
An-Yi Hung (洪安怡)
Chia-Hsuan Hu（胡家瑄）
Clinical Staff of Baby Room, YMUH
Participants & their Parents

Funded by:
National Science Council
Brain Research Center, YMU
YMU Hospital

Many Thanks for Your Listening!