Voice and Emotion Processing in the Human Neonatal Brain

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Are Humans Innately Social?
lessons from NEWBORNS

How Well Can Newborns See and Hear?

- At birth, babies see 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).

A voice region in the monkey brain

- Petkov et al. (2008)

Figure 1. Temporal Voice Areas in the Adult Brain
The contrast of emotional saliency measured in the adult brain by functional magnetic resonance imaging (fMRI) in response to auditory stimulation with vocal versus non-vocal sounds (Scherer et al. 2001, highlighting voice unpleasantness) is shown. Vocal listeners presented with the voice pleasantness condition elicited increased activity in the vocal regions located along the middle and anterior parts of the superior temporal sulcus (STS/sFS). (Scherer et al. 2001) Nature

Temporal Voice Areas

Auditory cortex

Vocal cortex

Non-vocal cortex

Superior temporal sulcus (STS)
Phylogeny and Ontogeny of Cerebral Voice Processing


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.
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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 centroid (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?

<table>
<thead>
<tr>
<th>Newborn Babies</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age (week)</td>
<td>38.8</td>
<td>4.5</td>
<td>36~40</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>3119</td>
<td>307</td>
<td>2755~3890</td>
</tr>
<tr>
<td>Age (day)</td>
<td>1.6</td>
<td>1.1</td>
<td>0~5</td>
</tr>
</tbody>
</table>

- 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).

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
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Exp. 2: Can Newborns Distinguish Emotions from Voices?

<table>
<thead>
<tr>
<th>Newborn Babies (N = 43, 23 boys)</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age (week)</td>
<td>38.5</td>
<td>1.1</td>
<td>37~40</td>
</tr>
<tr>
<td>Birth weight (gw)</td>
<td>3195</td>
<td>310</td>
<td>2600~3890</td>
</tr>
<tr>
<td>Age (day)</td>
<td>1.6</td>
<td>1.2</td>
<td>0~5</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Newborn Babies (N = 30, 19 boys)</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
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<tr>
<td>Gestational age (week)</td>
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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

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


Atypical eMMN in Chronic Schizophrenia

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
Phylogeny and Ontogeny of Cerebral Voice Processing

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