Development of the visual system and face processing: evidence from typical development and autism

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Outline

• Development of subcortical and cortical face processing systems
• Face processing deficits in autism
• Early visual system development in autism
Face processing in early infancy

• Infants prefer to look at faces over almost every other kind of stimulus.
• Even very young infants show behavioral evidence for recognition of a familiar (e.g., mother’s) face.
• What is the basis for this preference, and what are its developmental consequences?
Theories of early face preference

• Innate functioning of face specific brain region
Neural basis of face versus object processing

“Fusiform face area” (FFA) in temporal cortex

- Single-cell recordings
  (Macaque monkeys: e.g., Perret, Rolls, & Caan, 1982)
  (Humans: e.g., Allison & Bonds, 1994)

- Functional Magnetic Resonance Imaging
  (e.g., Kanwisher et al., 1997; Haxby et al., 1999)

- Positron Emission Tomography in infants
  (e.g., Tzourio-Mazoyer et al., 2002)

- Brain lesions in humans, prosopagnosia
  (e.g., Farah et al., 2000)
Theories of early face preference

• Innate functioning of face specific brain region
• Subcortical mechanism early in development
  – Later in development, faces are processed by both a subcortical and cortical pathway.

(Johnson, 2003)
Neonatal bias to attend to faces

Subcortical mechanism?

Morton & Johnson, 1991
Specificity of early face preference

- Infants prefer faces, but they also prefer geometric patterns that are “top heavy”
- Suggests that the “innate” face bias is a more general attentional mechanism.

Simion, et al, 2002
Subcortical Visual Processing Stream

Nasal Retina
(Schiller, 1979; 1985)

Magno Cells

Superior Colliculus
Nasal Retina

Magno Cells
(Schiller, 1985)

Superior Colliculus

Amygdala
Consequences of dysfunction in this system

- Early subcortical system is thought to lead into and influence the development of the later emerging cortical system
  - By directing infants’ attention to faces
  - Leads to increased experience with faces
- Failure to preferentially attend to faces
- Failure to find faces reinforcing?
- Failure to develop “expertise” system for face processing?
Exp 1: Face processing in autism
Characteristics of Autism

Social:

- use of eye contact and gestures
- sharing interest with others
- social-emotional reciprocity
Characteristics of Autism, continued…

Communication:
- language delay
- initiating conversations

Repetitive Interests / Restricted Behaviors

Symptom onset by 3 years of age
Decreased attention to faces early in life

Young children with autism
(e.g., Dawson et al., 1998)

Retrospective studies of videotapes
(e.g., Baranek, 1999; Maestro et al., 2002; Osterling, Dawson, & Munson, 2002)
Early-Stage Face Processing

ERP - N170

• Subset of EEG activity
• Averaged electrical response time-locked to repeated stimulus presentations
• Brainwave response recorded from electrodes over occipito-temporal cortex
  – Larger to faces than non-face stimuli
  – Slower and larger to inverted than to upright faces
Face-specific N170 Brainwave
Face-specific N170 Brainwave

![Graph showing N170 brainwave for faces and objects over time. The graph plots voltage (V) on the y-axis against time in milliseconds (ms) on the x-axis. The N170 deflection is prominent around 200 ms for both faces and objects. The graph indicates that faces elicit a larger N170 response than objects.]
Face-specific N170 Brainwave

![Graph showing Face-specific N170 Brainwave with labels for Faces, Objects, and Inverted Faces.]
Face perception in autism

Matching faces versus non-faces
(Hauck et al., 1998; Klin et al., 1999)

Face inversion effects
(Joseph & Tanaka, 2003; Langdell, 1978)

 Discriminating facial expressions of emotion
(DeRuelle et al., 2004; Weeks & Hobson, 1987)

Sensitivity to information in eyes versus mouth
(Hobson, Ouston, & Lee, 1988)
Neural basis of face processing deficit in adults with autism

• Reduced face-driven activity in FFA (?)
  (Schultz & Robins, 2005)

• No “face advantage” in latency of N170
  (McPartland, et al., 2004)

• No N170 face inversion effects
  (McPartland, et al., 2004)
Neural basis of face processing deficit in children with autism

• Abnormalities in early-stage face processing
  (Dawson et al., 2005)
• Abnormalities in later-stage attentional responses to faces
  (Dawson, et al., 2002)
• Atypical responses to emotional expressions
  (Dawson, et al., 2004)
• Atypical early-stage face versus object responses
  (Webb, et al., in press)
Early-stage processing in children with autism

TYPICAL

AUTISM

Webb et al., in press
N290 Amplitude Ratios

Webb et al., in press

Webb et al., in press
Early-stage processing in children with autism

TYPICAL

AUTISM

Webb et al., in press
N290 Latency Ratios

Webb et al., in press

Latency (milliseconds)

Face Advantage

Object Advantage

Webb et al., in press
Experiment 1

Early stage face and object processing in infant siblings of children with autism
Broader autism phenotype

Social skills, communication, cognition, brain
(e.g., Dawson et al, 2002; Fombonne et al., 1997; Hughes et al., 1999; Le Courter et al., 1996; Micali et al., 2004; Pickles et al., 2000; Piven et al., 1997; Rojas et al., 2004)

Early-stage face processing (Dawson et al., 2005)
- N170 Latency
- N170 Lateralization
Participants

Original sample

- 18 infant siblings of children with autism
- 36 infants with no family history of autism

Approximately 40% data loss
Final Sample

10 infant siblings of children with autism
- 5 female, 5 male

20 infants with no family history of autism
- 9 female, 11 male

Older siblings of at-risk infants
- 5 Autistic Disorder
- 1 Aspergers syndrome
- 4 PDD-NOS
EEG Sensor Net

124 Electrodes
Fast Application

Electrical Geodesics, Inc.
Face and Object Stimuli

**FACES**
- Mother’s face
- Stranger’s face

**OBJECTS**
- Favorite toy
- Unfamiliar toy
Inter-trial interval varied randomly between 500 and 1200 ms
Data Recording

Continuous EEG

250 Hz

Impedance: 80 kOhms

0.1 - 100 Hz bandpass filter

Cz reference
Data Analysis

40 Hz low-pass filter

Automated artifact rejection

Individual trial inspection

Replace up to 10 channels

Individual subject averages: Faces, Object

Average reference
Control Infants

Amplitude (microvolts)

Milliseconds

-100  -40  20  80  140  200  260  320  380  440  500  560  620

Amplitude (microvolts)

-10  -5  0  5  10  15  20  25

Control -Faces
Control -Objects
At-Risk Infants

Amplitude (microvolts)

At-Risk-Faces

At-Risk-Objects
Young children with autism (Webb et al., in press)
At-Risk Infants

Amplitude (microvolts)

Milliseconds

At-Risk-Faces
At-Risk-Objects
N290 Latency Ratios

Young children with autism (Webb et al., in press)
Conclusions

- Familial risk for autism is associated with abnormal face and object processing in the first year of life

- Early-stage brain electrical responses to faces and objects in at-risk infants are strikingly similar to those of young children diagnosed with autism

- Atypical specialization for face versus object processing in at-risk infants may put these infants at risk for social and communicative difficulties associated with autism and the broader autism phenotype
Experiment 2

• What is at the basis of the face processing deficit in autism?
• Assessing the integrity of the magnocellular versus parvocellular visual pathways in infant siblings of children with autism
Participants

Six month old infants

22 infant siblings of children with autism
  - 10 female, 12 male

133 infants with no family history of autism
  - 54 female, 79 male

Older siblings of at-risk infants
  - 12 Autistic Disorder
  - 1 Aspergers Syndrome
  - 9 PDD-NOS
Luminance Gratings

HIGH Luminance Contrast

MEDIUM Luminance Contrast

LOW Luminance Contrast

Chromatic Red/Green Gratings

HIGH Chromatic Contrast

MEDIUM Chromatic Contrast

LOW Chromatic Contrast
Forced-Choice Preferential Looking

(Dobkins et al., 1999)
Stimuli

11 degree by 11 degree sinusoidal gratings

3 cycle sinusoids

0.27 cycles per degree

4.2 Hz of motion

15 degree eccentricity
Results

At-Risk ($n = 22$)

Controls ($n = 133$)

Contrast Sensitivity

Luminance (Magnocellular)  Chromatic (Parvocellular)

* n.s.
Results, cont…

Difference Score
(Lum - Chr)

At-Risk
Control
Results, cont...

Difference Score (Lum - Chr)

At-Risk  Control

*
Conclusions

- At-risk infants in our study saw luminance stimuli better than controls

- Familial risk for autism may involve abnormal magnocellular processing

- Early magnocellular abnormalities may help explain decreased cortical specialization for face processing in families affected by autism
Conclusions, cont…

- Magnocellular processing abnormalities may help identify some children with autism in early infancy

- Our data add to evidence for a possible subtype of autism associated with magno stream dysfunction (e.g., Milne et al., 2006)

- Other sub-types may involve abnormalities in amygdala, frontal cortex, etc.
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