Feature binding of social and non-social stimuli in children with ASD

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BACKGROUND

Social Motivation Hypothesis

Social theories of autism, such as the social motivation hypothesis[1], postulate that limited social motivation and inattention to faces throughout development lead to decreased social experience and a cascading series of developmental deficits and atypical face-related brain activity. Within this framework, individuals with ASD possess an intact capacity for development of neural specialization for visual information.

Temporal Binding Deficit Hypothesis

In contrast, cognitive-perceptual theories of autism, such as the temporal binding deficit hypothesis[2], suggest that deficits in executive function, socialization, and communication in autism stem from a bias towards local or piecemeal rather than configural or global processing. Deficits in temporal binding result in reduced integration between neutral networks, or decreased feature binding of disparate features into a coherent, familiar percept. According to the temporal binding deficit hypothesis, the disruption in temporal synchrony of firing neurons leads to broad deficits in information integration in individuals with ASD.

The current study compares feature binding, as indexed by gamma band activity (GBA), in response to social versus non-social stimuli to investigate the specificity of perceptual coherence anomalies in ASD and to explore their consistency with cognitive-perceptual versus social theories of ASD. The former predicts atypical perceptual binding to both classes of stimuli, a reflection of problems with the feature-binding process itself; the latter suggests that anomalies would be evident only during perceptual binding of social stimuli, reflecting specific vulnerability with social information.

Gamma band oscillations index feature binding

Oscillatory activity in the high frequency gamma band has been suggested as a solution to the "binding problem" in cognitive neuroscience. The "binding problem" attempts to explain how the brain is able to process complex objects by summing together processing of a myriad of features—such as size, shape, luminance, etc.—from multiple cortical areas into a single, coherent representation. EEG analysis suggests that activity from multiple areas of the brain is synchronized to create a unified percept through bursts of gamma activity in the 30 to 80 Hz range[3,4]. This gamma activity may provide the links that bind together processing from multiple levels. Previous studies have shown gamma band oscillatory activity to be implicated in processing of both social information such as faces[5] and non-social information such as letters[6]. These studies suggest that prefrontal and occipitotemporal regions may be bound together via gamma synchronization to bind disparate features into a coherent percept. Gamma band activity has been shown to be reduced in children with ASD during processing of faces[7]. However, little is known about processing of non-social information in children with ASD.

METHODS

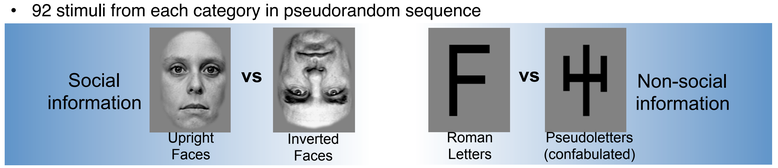
Participants:

Group	Mean IQ	Mean Age	# Male	# Right Handed
ASD (n = 19)	108 (83-141)	11 (8-16)	18 (94.7%)	18 (94.7%)
Typical (n = 19)	114 (92-142)	12 (8-16)	17 (89.5%)	18 (94.7%)

- Children with ASD met Autism Spectrum Disorder criteria on ADOS, ADI-R and DSM-IV-TR clinical diagnosis

Stimuli and Experimental Design:

- 92 stimuli from each category in pseudorandom sequence



- Trial structure:
  Crosshair (250-750 ms) → Stimulus (500ms) → Blank screen (500ms)
- Participants performed a one-back target detection task

Data Acquisition and Processing:

- EEG recorded continuously at 250Hz using Electrical Geodesics 256-channel sensor net
- Gamma band (30-80Hz) oscillations extracted at frontal and occipital electrode groups spanning 300ms window concurrent with stimulus onset

RESULTS

Figure 1: Right anterior GBA to faces is attenuated in ASD.
Left: Time-frequency plots of gamma band activity pulled from right lateralized anterior electrodes show expected increased power to upright over inverted faces in typical controls, while ASD group showed decreased GBA to both upright and inverted faces. Black outline indicates bootstrap significance to p=0.05 compared to baseline.
Right: Frequency-power plots show frequency band power as averaged over an epoch of 0 to 300ms after stimulus presentation. ASD group shows reduced and non-normative GBA.

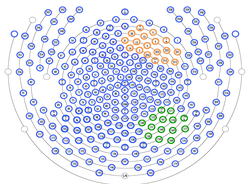
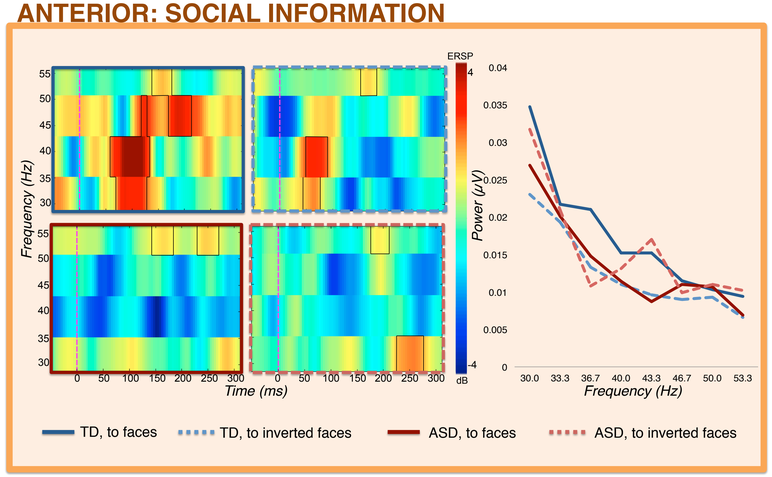
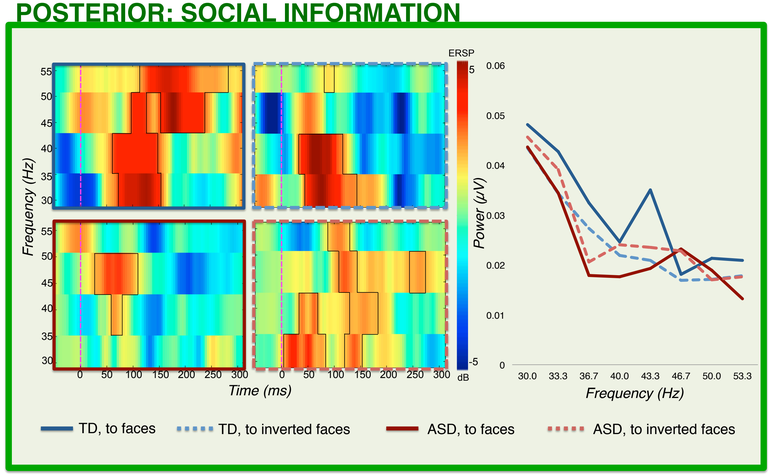


Figure 2: ASD group shows reduced GBA to faces in right posterior electrodes.
Left: Time-frequency plots of GBA in right lateralized posterior electrodes show reduced amplitude in ASD group in response to viewing upright versus inverted faces. Typical controls show expected results: inverted faces elicit attenuated GBA compared to upright faces. Black outline indicates bootstrap significance to p=0.05 compared to baseline.
Right: Frequency-power plots averaged over a 0 to 300ms epoch after stimulus presentation show reduced power in the gamma band compared to controls.

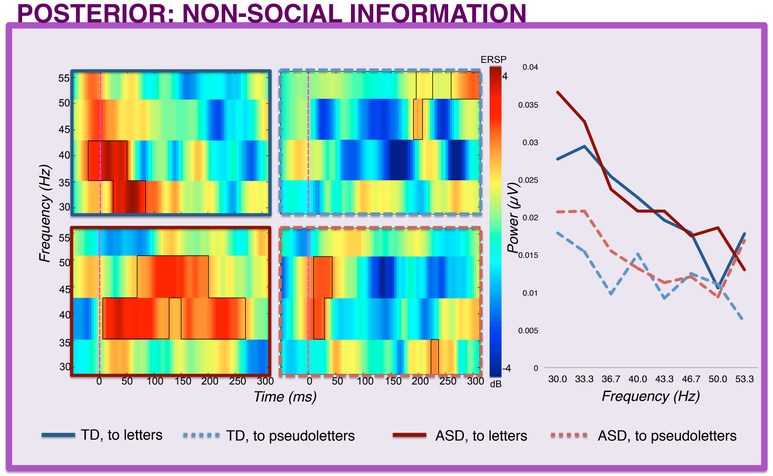
ANTERIOR: SOCIAL INFORMATION



POSTERIOR: SOCIAL INFORMATION



POSTERIOR: NON-SOCIAL INFORMATION



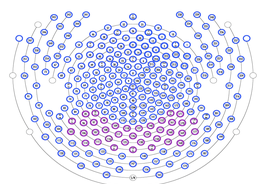


Figure 3: GBA to letters in ASD group elicits normative response.
Left: Time-frequency plots of EEG response to letters show normative patterns of GBA between ASD and TD controls. ASD subjects display a longer gamma burst to letters than controls. Outline indicates bootstrap significance to p=0.05 compared to baseline.
Right: Frequency-power plots averaged across 300ms show increased GBA to letters over pseudoletters in both groups.

CONCLUSIONS

Observed differences in electrophysiological markers of face perception in ASD have been interpreted according to several theoretical frameworks. This study evaluates these theories by investigating gamma band activity as a neural marker of integration of visual information for social and non-social percepts.

Decreased temporal binding of social information

Consistent with previous findings, our results show decreased GBA to faces in ASD participants compared to typical controls, suggesting atypical neural synchrony and temporal binding of social visual information.

- The ASD group exhibited attenuated activity in the lower gamma band (30-60Hz range) to both upright and inverted faces compared to controls, replicating prior work[7]
- Effects were lateralized to right anterior and posterior electrodes, corresponding to prefrontal and occipitotemporal regions, respectively
  - Left lateralized regions did not show differences in GBA to upright versus inverted faces in either typical or ASD groups
- Reduced gamma activity in general compared to previous studies of adults suggests immature development of information processing mechanisms

Normative patterns of temporal synchrony to non-social information

GBA in the ASD group in response to letters was comparable to typical controls, suggesting intact information processing in ASD for non-social visual information.

- Both ASD and typical groups showed increased gamma synchrony to letters over pseudoletters in the lower gamma band (30-60Hz)
  - 300ms after stimulus presentation, GBA of letters versus pseudoletters strongest at approximately 40Hz for both groups
- GBA observed in posterior electrodes (right and left lateralized, corresponding to occipitotemporal regions), consistent with prior literature[6]
  - Stronger effects seen in right hemisphere electrodes
  - Anterior electrodes did not exhibit gamma synchrony
- ASD group showed GBA over a longer time period (50-250ms) compared to controls

By examining GBA as an index of feature binding, this study sheds light on neural mechanisms for configural processing of visual information in ASD. Previous studies of face detection using event-related potentials (ERPs) have shown that deficits in visual perception primarily occur in social information processing with intact processing in non-social domains[8]. The results of this study suggest that the deficits in feature binding predicted by the temporal binding deficit hypothesis are specific to social information, emphasizing the import of the visual content being processed when evaluating visual-perceptual mechanisms in ASD.

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