Interactive Social Neuroscience to Assess Reward Processing in the Broad Autism Phenotype

Max Rolison, Adam Naples, Ph.D., John Herrington, Ph.D., & James McPartland, Ph.D.

McPartland Lab
Yale Child Study Center, New Haven, CT

Background

- Autism Spectrum Disorder (ASD) is hallmarked by interpersonal difficulties, yet scant published neuroscience research investigates actual social interactions
- Atypical reward processing is implicated in ASD; few studies have dissociated social versus non-social reward in ecologically valid contexts
- This study utilized interactive social neuroscience methods to examine reward processing in a social context and its association with autistic traits in typically developing (TD) adults
- Using simultaneous recording of electroencephalogram (EEG) and electrocardiogram (ECG) in pairs of people competing in a computer game, we examined reward processing (indexed by event-related potentials [ERP]), heart rate variability (HRV), and their association with autistic traits
- **Objectives:** Characterize neural and cardiac markers of reward and feedback processing and their association with autistic traits during live, face-to-face social interactions

Method

Participants:
- 16 TD adults (6 male), grouped in same-sex dyads, recruited from the Yale University community
- Participants completed the Autism Quotient (AQ), the Broad Autism Phenotype Questionnaire (BAPQ), and the Social Responsiveness Scale – Adult Self-Report (SRS-A-SR) to assess social function and dysfunction, as well as the Interpersonal Reactivity Index (IRI), a measure of empathy

	Mean (SD)
Age (years)	21.7 (0.5)
AQ	14.0 (4.9)
BAPQ	86.2 (24.3)
SRS	33.6 (23.1)
IRI	70.8 (10.6)

All behavioral data reported as raw scores

Resting Paradigm:
- Dyads sat quietly for two minutes with their eyes closed (EC) and eyes open (EO) while in (1) separate rooms, (2) the same room with their backs to each other, (3) the same room while facing each other

Treasure Hunt Paradigm (Figure 1):
- Participants were seated in front of a computer screen with a 10x10 square grid displayed, with scores displayed below, and a mouse to control the game
- Players were told they were searching for buried treasure and were competing against their opponent to win treasure points
- Upon selecting a spot, feedback was presented on the screen indicating a win (circle) or loss (square)
- Participants alternated turns and each viewed the same feedback simultaneously (one actor and one observer)
- Participants played the game against the computer and then against one another, while facing each other

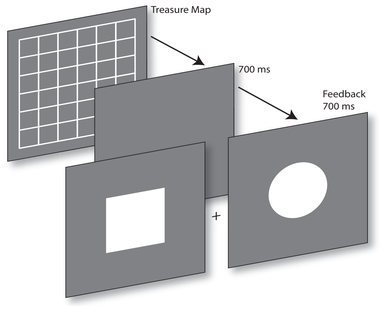

Figure 1: Trial sequence for win and miss conditions. Participants were shown a treasure map for unlimited duration. Once they selected a box, a blank screen appeared for 700 ms, followed by feedback about whether they found (circle, "win") or did not find (square, "miss") treasure for 700 ms, followed by a blank screen for 700 ms. Participants alternated between acting and observing on sequential trials.

EEG and ECG Data Acquisition and Collection:
- Recorded at 256 Hz using Advanced Brain Monitoring X-24 EEG sensor net
- 20 electrodes placed according to international 10-20 system with mastoid reference
- ECG recorded with electrodes placed on chest

ERP Analysis:
- P1 and N2 are ERP components marking early visual processing
  - P1: Max. amplitude 100-200 ms over O1 and O2
  - N2: Min. amplitude 100-250 ms over O1 and O2
- Feedback Related Negativity (FRN) and P3 are ERP components associated with reward processing
  - FRN: Mean amplitude 250-365 ms over Fz and Cz
  - P3: Max. amplitude 310-465 ms over Cz, Pz, and POz

Statistical Analysis:
- Peak amplitude analyzed using repeated measures ANOVA
- Competitor (computer/person) x Outcome (win/loss) x Player (self/opponent)
  - All within-subjects variables
- Post-hoc paired samples t-tests to examine interactions
- Differences between conditions correlated with behavioral measures

Results

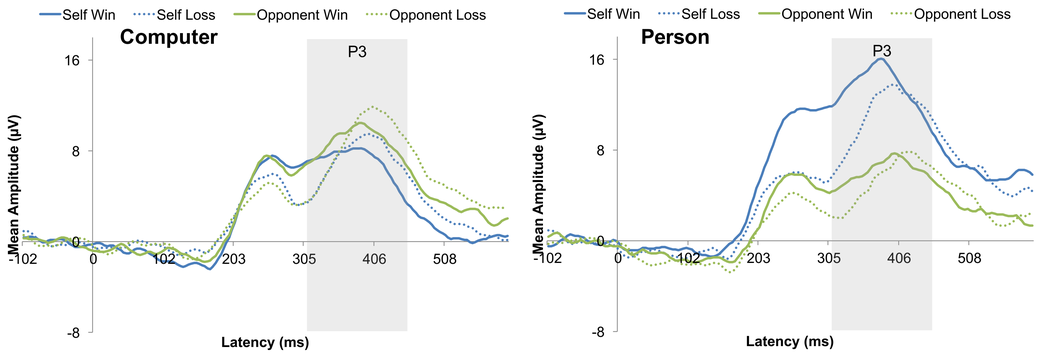

Figure 2: Grand average waveforms depicting the P3 while playing against a computer (left) and another person (right). P3 was extracted as the maximum amplitude 310-465 ms over Cz, Pz, and POz.

P3 amplitude:
- Significant main effect of player [$F(1,15)=8.035$, p =0.013, $\eta^2_{partial}=0.349$] self >
- Significant interaction effect between player and competitor [$F(1,15)=14.102$, $p=0.002$, $\eta^2_{partial}=0.485$]
  - Post-hoc paired samples t-tests revealed significantly greater P3 amplitude for both self-win [$t(15)=2.357$, $p=0.032$, d=1.011] and self-loss [$t(15)=2.400$, $p=0.030$, d=0.626] when playing against another person versus against a computer
  - When playing against another person, P3 amplitude was greater for self-win than both opponent-win [$t(15)=3.769$, $p=0.002$, d=1.353] and opponent-loss [$t(15)=3.635$, $p=0.002$, d=1.199]
  - P3 amplitude for opponent-win was greater than for self-loss [$t(15)=-4.701$, $p<0.001$, d=-1.157], and the amplitude for self-loss was greater than for opponent-loss [$t(15)=3.774$, $p=0.002$, d=0.987]

FRN amplitude:
- Significant main effects of outcome [$F(1,15)=15.621$, $p=0.001$, $\eta^2_{partial}=0.510$] and player [$F(1,15)=6.725$, $p=0.020$, $\eta^2_{partial}=0.310$]
- No main effect of competitor [$F(1,15)=2.103$, $p=0.168$, $\eta^2_{partial}=0.123$]
- Significant interaction between competitor and player [$F(1,15)=49.659$, $p=0.007$, $\eta^2_{partial}=0.392$]
- Post-hoc paired samples t-tests revealed significantly more negative FRN amplitude in response to both self-win [$t(15)=2.257$, $p=0.039$; d=0.828] and self-loss [$t(15)=3.311$, $p=0.005$; d=0.686] when playing against a computer versus when playing against another person
- When playing against another human, self-win generated am attenuated FRN amplitude compared to opponent-win [$t(15)=3.696$, $p=0.002$; d=1.303], self-loss [$t(15)=2.396$, $p=0.030$; d=0.702], and opponent-loss [$t(15)=6.165$, $p<0.001$; d=1.619]
- When playing against another person, self-loss generated a significantly less negative FRN amplitude than opponent-win [$t(15)=-2.415$, $p=0.029$, d=-0.639], and opponent-loss resulted in a more negative FRN amplitude than self-loss [$t(15)=2.616$, $p=0.019$, d=0.853]

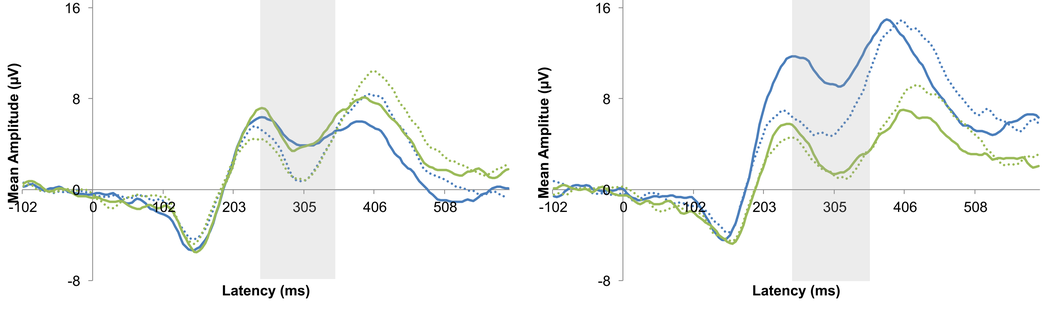

Figure 3: Grand average waveforms depicting the FRN while playing against a computer (left) and another person (right). FRN was extracted as the mean amplitude 250-365ms over Fz and Cz.

Behavioral Correlations:
- Sensitivity to feedback, indexed by the FRN, during live, but not computer, competition was correlated with autistic traits
  - Significant correlation between AQ (r = -0.505, p = 0.046) and BAPQ (r = -0.558, p = 0.025) scores and difference in FRN amplitude between self-win and opponent-win when playing against another person
  - BAPQ score was correlated with differences in FRN amplitude between self-win and opponent-loss when playing against another human (r = -0.544, p = 0.03) and with the difference in FRN amplitude for opponent-win versus self-loss (r = 0.526, p = 0.036)
- Sensitivity to reward during live interaction, indexed by the P3, was correlated with autistic traits
  - SRS scores were correlated with the difference in P3 amplitude when playing against another person versus a computer for self-loss (r = -0.498, p = 0.049)
  - BAPQ scores were correlated with the difference in P3 amplitude between self-win and opponent-win conditions when playing against another person (r = -0.516, p = 0.041)
  - BAPQ scores were correlated with difference in P3 amplitude between opponent-win and self-loss conditions when playing against another person (r = 0.524, p = 0.037)

P1 amplitude: No significant main effects of outcome, player, competitor, or interactions for P1 amplitude were observed [all Fs <2.6, all ps>0.126]

N2 amplitude: No significant main effects of outcome, player, competitor, or interactions for N2 amplitude were observed [all Fs<1.8, all ps>0.10]

Heart Rate Variability While Resting:
- No significant main effects of outcome, player, competitor, or interactions for HRV while resting
- Significant correlation between difference in HRV between eyes-closed with backs to one another versus eyes-closed alone and IRI score (r = 0.671, p = 0.009)

Conclusions

- This study applied interactive social neuroscience to investigate reward processing during live interaction in TD adults
- This was the first study to examine electrophysiological indices of reward-feedback monitoring during live dyadic interaction
- Results reveal task-specific modulation of brain activity during live interaction that is absent during computer interaction
- Individuals with lower levels of autistic traits exhibited greater sensitivity to outcome during live interaction versus playing alone
- Our findings reveal potential mechanisms of social impairment associated with autistic traits and emphasize the import of utilizing more ecologically valid approaches in neuroscientific studies of social brain function

Acknowledgments
Autism Science Foundation (Rolison); NIMH R01 MH100173 (McPartland); NIMH R01 MH100173-02S1 (McPartland); INSAR Slifka/Ritvo Innovation in ASD Research Award (Naples)