

Gaze Contingent Games to Modify Neural Response to Eye Contact in ASD

Adam Naples, Rachael Tillman, Emily Levy, Hannah Reuman, Michael Plöchl, & James McPartland
McPartland, Lab, Yale Child Study Center, New Haven, CT

Background

Decreased eye contact represents a common manifestation of social dysfunction in autism spectrum disorder (ASD). Prior electrophysiological research on gaze perception in ASD has focused on passive observation of social information, failing to address the interactive nature of eye contact.

Behavioral treatments designed to improve eye contact are resource intensive. Automated intervention methods, such as computer games, are potentially more efficient but have historically lacked the contingency and synchrony that characterize true social interactions and are considered requisite for social skills treatments.

We explored the effects of a brief interactive game on visual attention to faces and temporal dynamics of the neural response to shared gaze in individuals with ASD and typically developing controls. We explored group differences as well as the time course of change in visual attention over the course of the game. We predicted specific modulation of face-sensitive ERPs in response to changes in gaze in the typically developing individuals but not in the individuals with ASD. We further explored the relationship between change over the course of the game and clinical characterization.

Method

Participant Demographics			
	Male	Female	Mean age
ASD	4	3	13.85
TD	4	6	14.96

All participants had Full Scale IQs greater than 70.

ERPs were recorded at 500hz using a 128 electrode Hydrocel Geodesic Net and Netstation v 4.5. Eye-tracking (ET) was concurrently recorded at 500hz from a SR-Research Eyelink 1000 integrated with a stimulus presentation computer running Psychtoolbox.

Participants completed a gaze-mediated game where they would earn points by either reciprocating or following the gaze of an onscreen face. The experiment was composed of 8 blocks of 32 trials (16 reciprocal gaze and 16 gaze following trials). After each block participants saw an animated points screen depicting their score on the preceding block.

Trials began with presentation of a centrally presented fixation point, followed by a centrally presented neutral face looking down. Contingent upon participant gaze to the face, the face blinked and opened its eyes to display direct gaze or cued gaze (pointing to one of four treasure chests in the corners of the screen). In the direct gaze condition, participants were rewarded with a smile after maintaining gaze with the onscreen face for 800ms. In the cued gaze condition, participants earned a jewel by looking to the cued treasure chest for 600ms.

EEG was segmented to changes in gaze (informative gaze) from a closed eye face (direct gaze [4A] and cued gaze [4B]) and from onset of feedback to looking at the correct target (smiling face [5A] or jewel [5B]). In this way, we examined ERPs to informative gaze (direct gaze and cued gaze) and feedback (smiling face and jewel). EEG was segmented from -200ms prior to 600ms post change. N170 ERP components were calculated from right occipito-temporal electrodes in a time window extending from 150 to 275ms.

Independent components analysis was used to remove ocular artifact. By synchronizing ET with EEG we were able to identify those segments of the EEG that exhibited more activity during eye movements than stable fixations. The ratio of variance for components was calculated between activity during fixation and saccades. Those components exhibiting ratios in excess of 1.1 (10% more variance during saccades vs. fixation) were removed. This approach has been empirically validated to outperform other methods of ocular artifact removal.¹

REFERENCES

- Plöchl, M., Ossandón, J. P., & König, P. (2012). Combining EEG and eye tracking: identification, characterization, and correction of eye movement artifacts in electroencephalographic data. *Frontiers in human neuroscience*, 6.
- Dawson, G., Jones, E. J., Merkle, K., Venema, K., Lowy, R., Faja, S., ... & Webb, S. J. (2012). Early behavioral intervention is associated with normalized brain activity in young children with autism. *Journal of the American Academy of Child & Adolescent Psychiatry*, 51(11), 1150-1159.

Funding Sources
Autism Speaks Translational Postdoctoral Fellowship (Naples)
Autism Science Foundation Research Enhancement Grant (Naples)
NIMH R01 MH100173 (McPartland)
NIMH K23 MH086785 (McPartland)
Patterson Trust 13-002909 (McPartland)
CTSA Grant Number UL1 RR024139 (McPartland)
Waterloo Foundation 1167-1684 (McPartland)
Patterson Trust 13-002909 (McPartland)

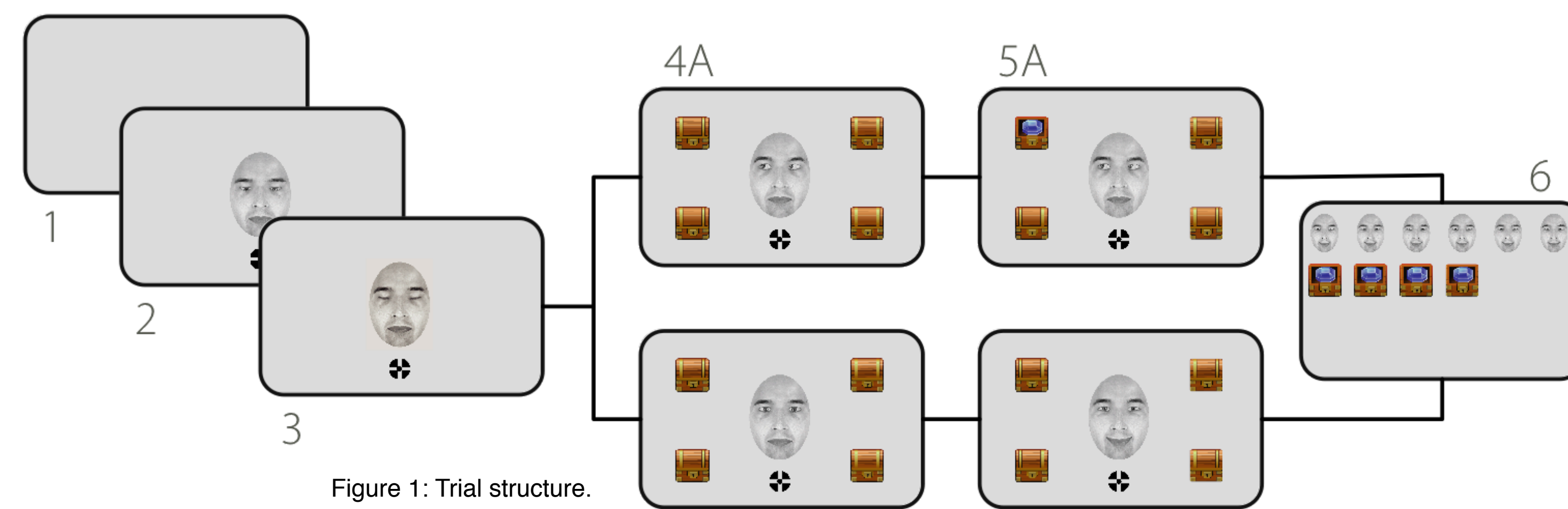


Figure 1: Trial structure.

- A blank screen is followed by a centrally presented fixation point.
- Following fixation to the point for 200ms, a centrally presented face appears looking down.
- Following fixation to the eyes of the face, the face blinks for 500ms.
- The face opens its eyes displaying either (4A) direct gaze or (4B) cued gaze.
- The participant maintains eye contact eliciting a smile (5A) or follows gaze revealing a jewel (5B) for 900ms.
- After each block of 32 trials, a prize screen depicts how many points the participant earned in the preceding block.

Results

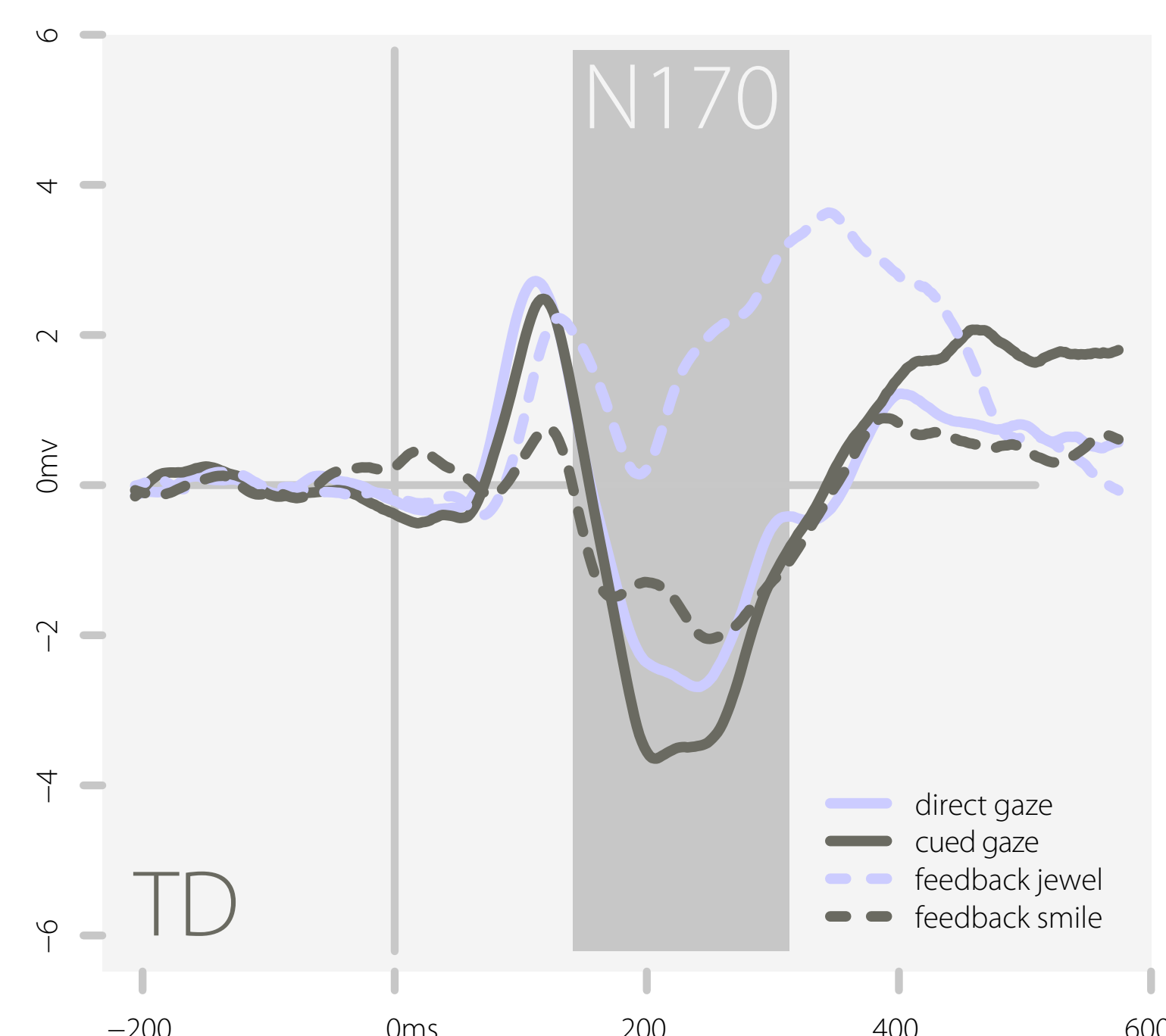


Figure 2: Waveforms depicting brain response to informative gaze and feedback in TD (top) and ASD (bottom).

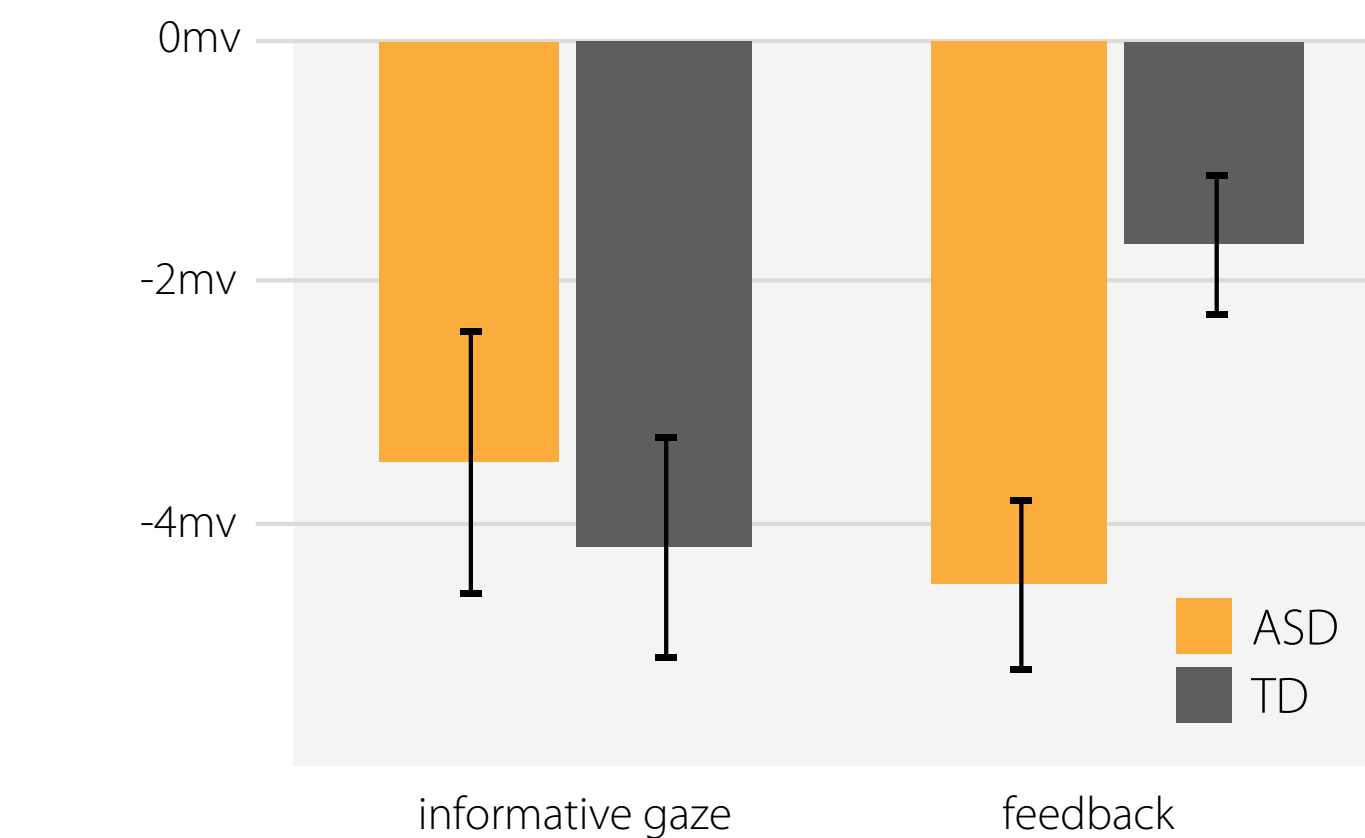
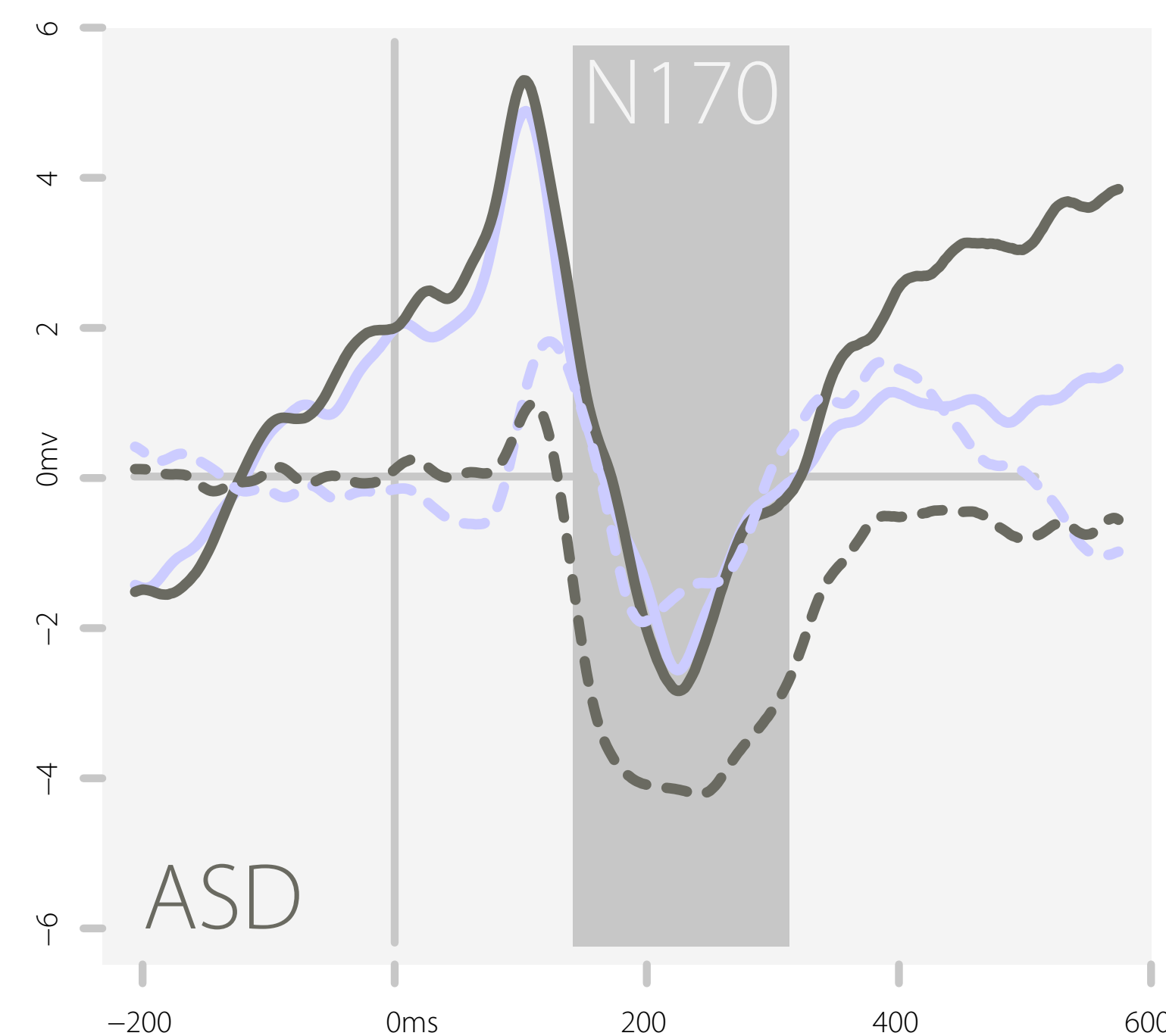


Figure 3: N170 amplitude to informative gaze (direct gaze and cued gaze) and feedback (smile and jewel) in TD and ASD.

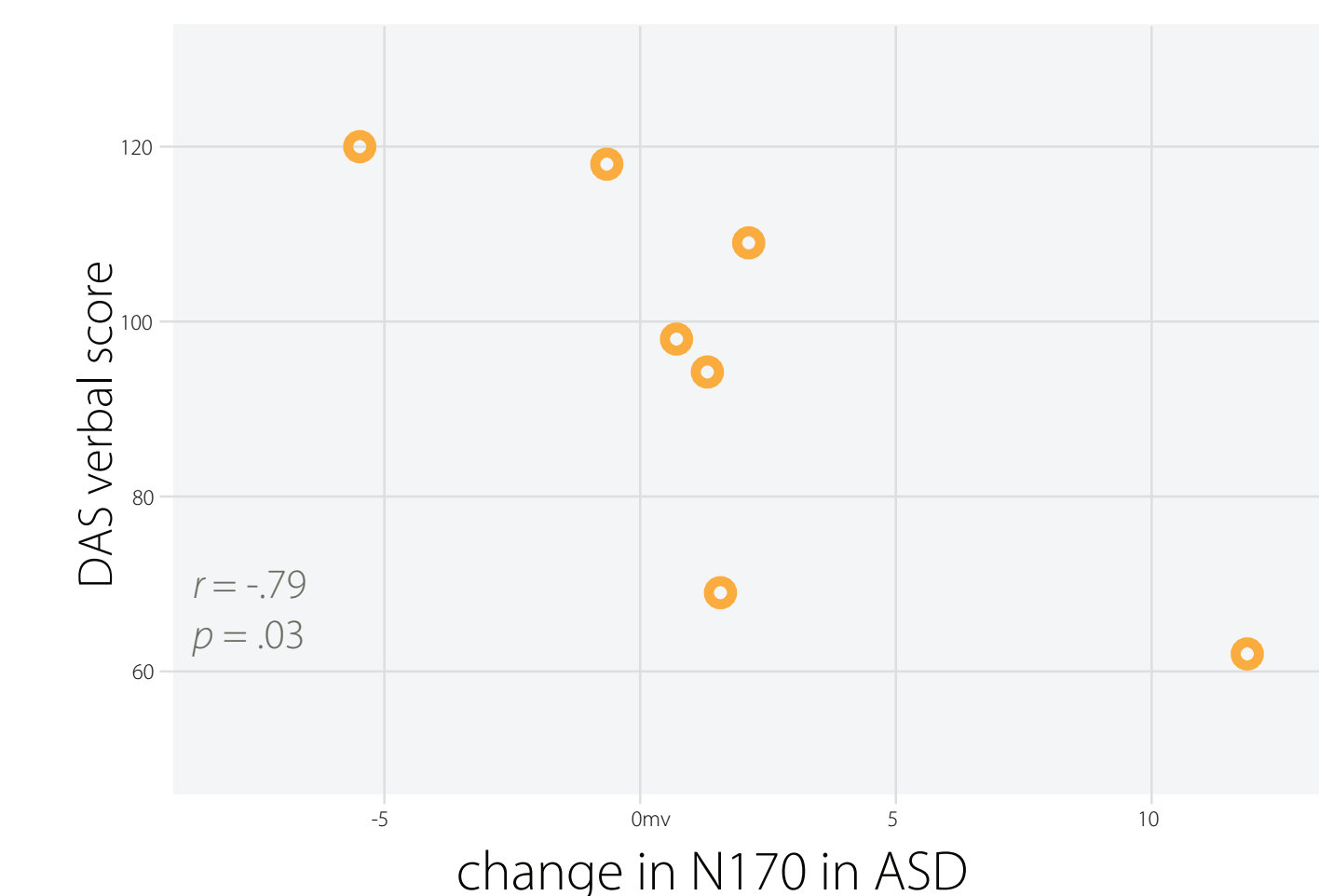


Figure 4: Scatterplot showing the relationship between change in N170 amplitude in cued gaze and language function.

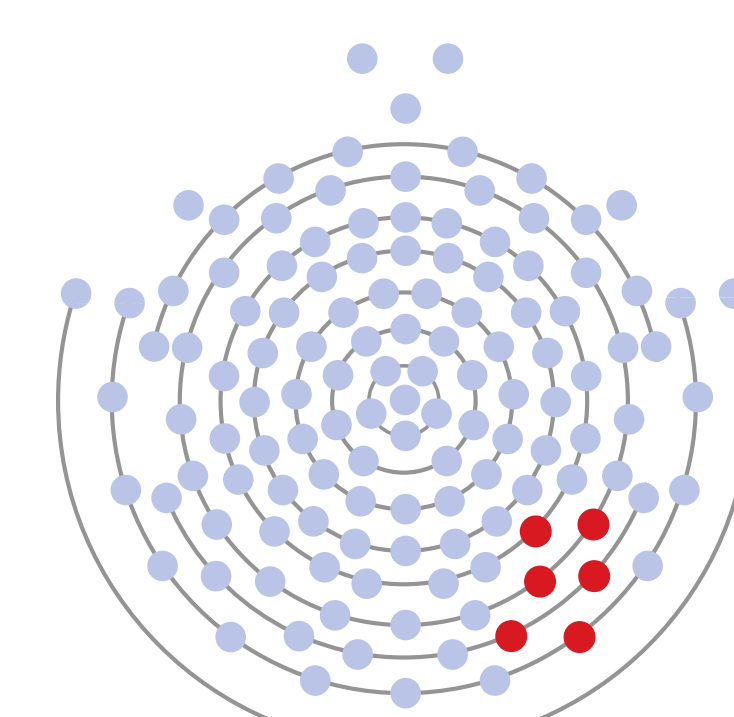


Figure 5: N170 recording sites.

Results

Figure 6: Change in ET latency (ms) across blocks between groups.

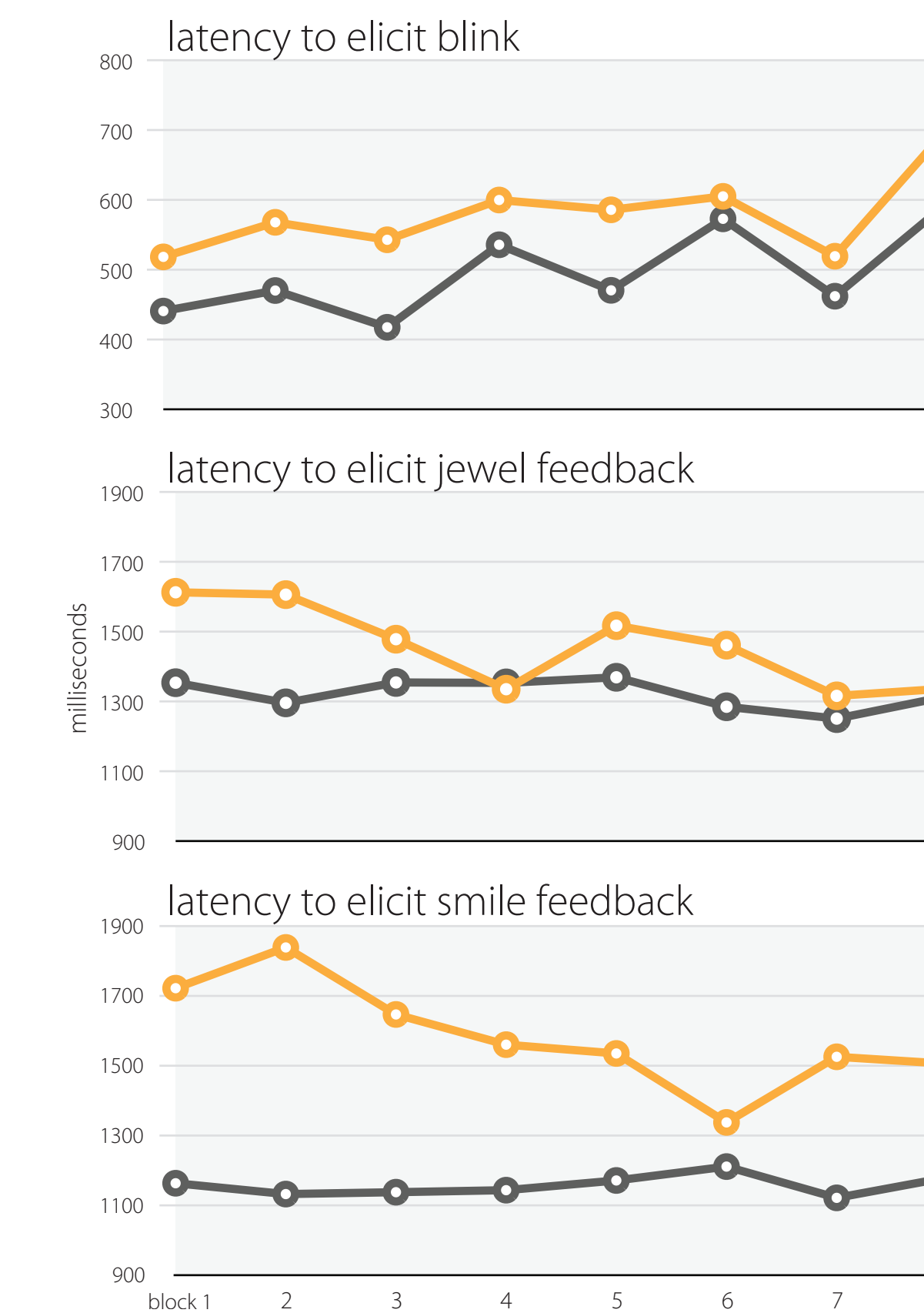
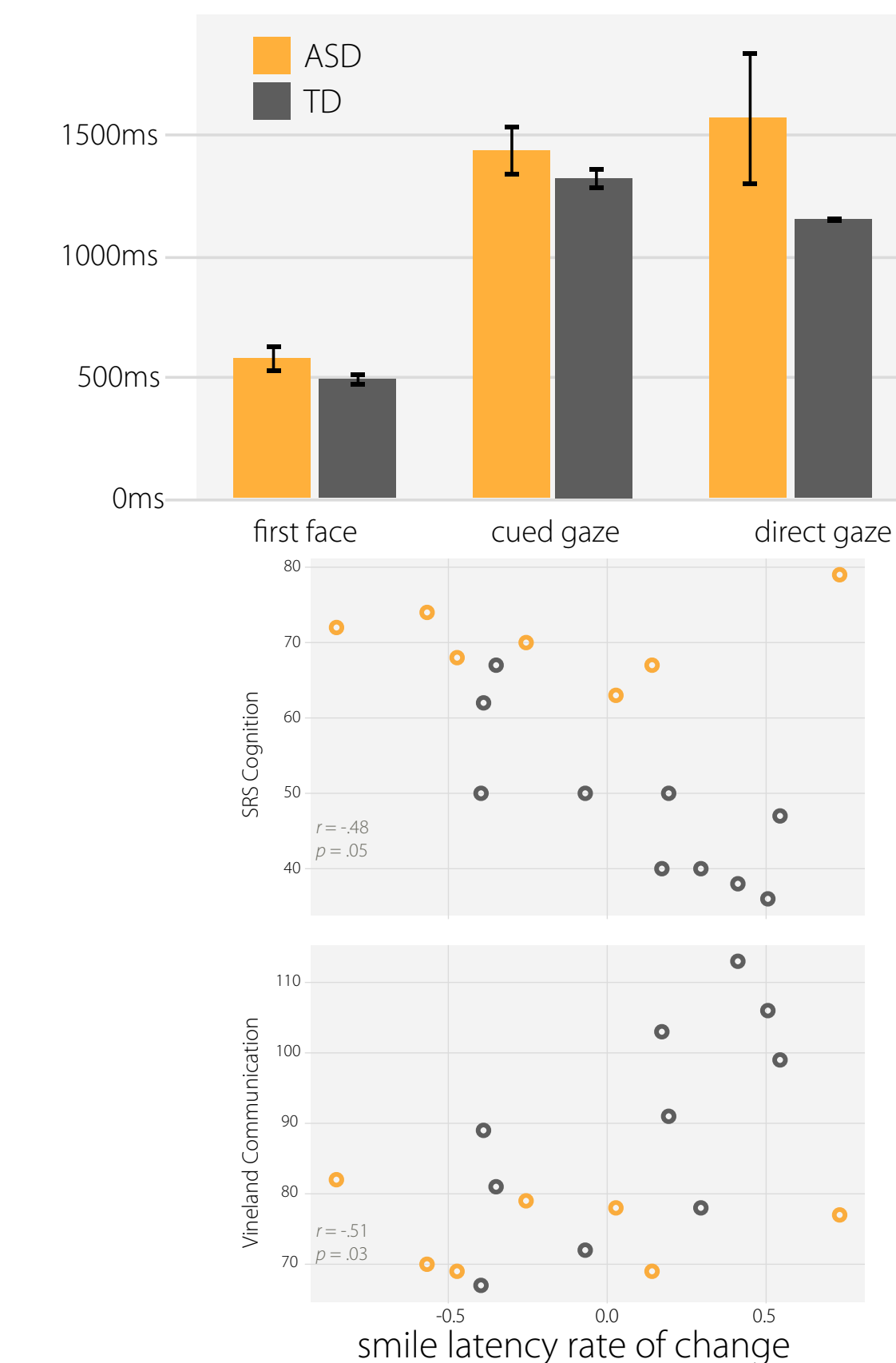


Figure 7: Differences in ET latency across all conditions (top). Correlations between slope of ET change and behavioral measures (bottom).



- N170 amplitude for informative gaze trials (direct and cued gaze) and feedback trials (smile and jewel) were compared across groups revealing a significant group by condition interaction [$F(1,15) = 4.8, p = .045$]. This was followed by between group comparisons showing that TD individuals showed discrimination between informative and feedback conditions ($t(9) = 3.8, p = .01$) but ASD individuals did not ($t(6) = .646, p = .54$).

- Change in N170 amplitude in the cued gaze condition (difference between mean N170 amplitude in the second half of the experiment and the first half of the experiment) in the ASD group correlated with verbal ability as measured by the DAS-II ($r = -0.79, p = .03$). Higher verbal scores on the DAS-II predicted increased sensitivity to gaze cueing over the course of the game.

- Latency to elicit change between conditions was longer in individuals with ASD, with marginal significance in eliciting a smile condition ($t(8) = 1.8, p = .09$).

- Across blocks, individuals with ASD exhibited a trend for longer latencies at the outset of the game ($t(15) = 1.9, p = .067$ for block 1) for direct gaze trials but approximated typical performance over the course of the experiment ($t(15) = 1.3, p = 0.22$ for block 8).

- To estimate individual differences in performance improvement, correlations between latency to elicit smile feedback for each block over the course of the game were examined. For the direct gaze condition across all participants, these values correlated with adaptive communication (Vineland-II communication; $r = 0.51, p = .03$) and social cognition (SRS cognition subscale; $r = -.48, p = .05$) such that greater latency change associated with poorer communication.

Conclusions

- Individuals with TD exhibit preferential neural response to informative gaze as compared to feedback, whereas individuals with ASD failed to display differential brain activity to gaze cues compared to feedback cues.
- Rate of change in brain activity in the ASD group was predicted by language function, consistent with prior research showing a relationship between EEG response to faces and intervention outcomes.²
- Individuals with ASD exhibited slower responses to cued gaze in early trials. Over the course of the experiment, they improved performance, eventually approximating the performance of TD children.
- An association between change in latency to cued gaze and social function suggests that individuals with lower levels of adaptive communication display the most improvement during game play.
- Results replicate prior findings of attenuated brain response to reciprocal gaze in ASD and indicate that this neural marker of social perception is modifiable.
- These findings suggest potential clinical utility of interactive neuroscience methods to monitor and shape gaze and related brain activity.