Brain signatures of social and non-social decision making in children with Autism Spectrum Disorder (ASD) and Attention-Deficit/Hyperactivity Disorder (ADHD)

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INTRODUCTION

A recent decision-making framework [1] has proposed an extended common currency model which assumes that similar neural processes assign motivational relevance to social and non-social choices. This model predicts that difficulties in the brain's value representation of rewards could affect the development of both social and non-social processes. Afterwards, these shared value representations rely on others domain-specific brain regions in social versus non-social choice contexts.

In the current study we used this model to explore the share and disorder-specific neural mechanism that underlie decision-making difficulties in ASD and ADHD children. To this aim, we used high-density electroencephalography (hdEEG) while participants performed event related potential (ERP) paradigms. For non-social decision making we employed a children's version of the Iowa Gambling Task (IGT, 2) in which participants win and lose money by selecting cards from high versus low risky decks. For social decision making we used a modified version of the Prisoner's Dilemma Game (PDG) [3] in which participants observed a game between two and six players who select cooperative and betrayal choices to gain money. The participant was identified by the fair player and received the final profit.

Following predictions from the extended common currency model, we expect to find that deficits in the neural processing of rewards during social non-social choices should be also presented in the brain valuation of rewards in social decision making. These predictions would affect differently to both ADHD and ASD children. First, given that ADHD children commonly present with difficulties in reward processing [4] they would show a reduced IERN responses and ACC activation in both social and non-social decision making paradigms. Contrary, considering that ASD children typically show intact reward processing, they would show normal IERN modulation and ACC activation during non-social choices in the IGT.

RESULTS

Social decision-making:

As we expected, children showed higher IERN responses for betrayal options compared to cooperation choices (see Figure 3C). ASD children exhibited the opposite pattern: higher IERN responses for cooperation choices compared to betrayal decisions. ADHD participants show no significant differences between betrayal and cooperation choices.

Similarly, the source reconstruction analysis showed that control participants exhibited a greater activation in the right ACC for betrayal choices compared to cooperation options, while the opposite activation was observed in the ASD group (see Figure 4C). No activation in this source was observed in the ADHD group.

CONCLUSIONS

In this study we used a common currency decision making framework [1] to explore the share and disorder-specific neural mechanism that underlie decision-making difficulties in ASD and ADHD children. Our results showed that ADHD children exhibited reduced IERN responses during both non-social and social decision making task. Contrary, ASD children only showed abnormalities in IERN responses during social decision making task while intact IERN modulation during non-social choices (IGT-C).

These results suggest that value-based neural processing deficits in ADHD may affect the value representation of rewards in both social and non-social decision making tasks. This reward processing was intact in ASD children during the non-social task while deficits appeared during the consideration of others in the social decision making task. This is the first report that used the common currency model to explain decision making difficulties observed in psychosis.

REFERENCES


ACKNOWLEDGMENTS

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METHODS

Table 1: Means (SD) and group differences in demographics and diagnostic symptoms.

<table>
<thead>
<tr>
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<th>ASD patients</th>
<th>ADHD patients</th>
<th>Control patients</th>
<th>p*</th>
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<tr>
<td>Age</td>
<td>10.39 (2.06)</td>
<td>11.67 (2.45)</td>
<td>11.43 (2.40)</td>
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<tr>
<td>Fluid intelligence</td>
<td>40.14 (9.39)</td>
<td>39.89 (8.10)</td>
<td>39.10 (6.55)</td>
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<td>ASD symptoms [3d]</td>
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<td></td>
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<tr>
<td>Social communication deficits</td>
<td>13.26 (4.17)</td>
<td>3.84 (3.79)</td>
<td>.000</td>
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<tr>
<td>Restricted and repetitive behaviors</td>
<td>5.85 (2.54)</td>
<td>1.18 (1.69)</td>
<td>.000</td>
<td></td>
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<tr>
<td>ADHD symptoms [CRS-RS]</td>
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<td>Inattention</td>
<td>9.75 (4.62)</td>
<td>11.64 (4.27)</td>
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<td>Hyperactivity</td>
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<tr>
<td>ADHD index</td>
<td>18.72 (7.01)</td>
<td>33.79 (6.72)</td>
<td>.048</td>
<td></td>
</tr>
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</table>

* ANOVA two-tail test. 3d: Developmental, Diagnostic and Dimensional Interview. CRS-RS: Conner's Parent Rating Scale Revised: Short form.

Non-social decision making task: IGT for children (IGT-C)

Participants were instructed to select a card from either the left or the right deck by pressing 1 or 2, respectively (see Figure 1A). Their goal was to maximize an initial capital (1200). Every time a card was selected, an outcome display revealed the magnitude of win and loss. After 20 choices, an outcome display revealed the accumulative feedback. The task finished after the 8th outcome display (160 trials). Participants were blind to both the distribution of win and loss between decks and the number of trials in each task (see Figure 1B). Participants were informed that they would receive chocolates after task completion, according to the accumulated money.

Social decision making task: PDG for children (PDG-C)

In the PDG-C participants observed a virtual game between two players who independently choose to either cooperate with each other or not (betray). Each player was awarded points that depend upon the interaction of both players choices. Unbeknown to the participants, the game was rigged such that one of the players (Simon in 1 player) mostly chose to cooperate whereas the other (Peter, the unfair player) mostly betrayed (see Figure 2A). Accordingly, we presented different frequency for the four possible outcomes (see Figure 2B). Through task instruction, we manipulated the participant's identification with the fair player, by indicating that participants would receive a reward according to the points accumulated by this player.

hdEEG and data analysis: 128-channel hdEEG signal was recorded using a Biosemi amplifier, sampled at 1024 Hz and referenced to linked mastoids. In both ERP paradigms, we analyzed the feedback-error related negativity (fERN) between the 280 and 400 ms after feedback presentation. The fERN was compared in both tasks between conditions of interest (win versus loss in the IGT-C and cooperation versus betrayal in the PDG-C) in the Fz electrode. Differences among conditions were assessed for significance via Monte Carlo permutation tests with bootstrapping [6]. Cortical sources were reconstructed with Brainstorm [7].

Figure 1: Example of a trial sequence of the IGT-C

Figure 2: Example of a trial sequence of the PDG-C

Figure 3: ERP of social and non-social decision making tasks in the ASD, ADHD, and control groups

Figure 4: Source reconstruction at the ACC during social and non-social decision making tasks in the ASD, ADHD, and control groups