Distinct but Effective Neural Networks for Facial Emotion Recognition in Individuals with Autism: A Deep Learning Approach

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Background

1. Individuals with ASD evince deficits in facial emotion recognition (FER; Lozier et al., 2014)
2. Failure to *encode* FER information OR to deploy correctly-encoded information (Yang et al., 2018, Dawson et al. 2005)
Background

1. Deep Convolutional Neural Networks (Deep ConvNets)
   ○ Isolate neural networks for encoding FER using single-trial EEG
2. Deep ConvNets can determine if those with ASD correctly encode FER similarly to non-ASD individuals
Outline

1. Experiment Design / Participant Samples
2. Deep ConvNet Architecture
   - Performances Results
3. iNNvestigate package
   - Saliency/Feature-importance Results
4. Conclusions
Questions and Hypothesis

1. Are face emotion recognition (FER) deficits in ASD exhibited at the level of neural encoding?
   ○ Can Deep Learning successfully decode emotion recognition from neural activity elicited by the viewing of faces?

1. What is distinct about the way individuals with ASD are encoding emotions, when and where do they do so?
## Experiment Design - Participants Sample #1

|                      | TD  
<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>N = 48</td>
</tr>
<tr>
<td><strong>μ or #</strong></td>
<td></td>
</tr>
<tr>
<td><strong>σ or %</strong></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>16.73</td>
</tr>
<tr>
<td>Male N, %</td>
<td>29</td>
</tr>
<tr>
<td>ADOS-CSS</td>
<td>3.33</td>
</tr>
<tr>
<td>IQ</td>
<td>107.82</td>
</tr>
</tbody>
</table>

|                      | ASD  
<table>
<thead>
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</thead>
<tbody>
<tr>
<td></td>
<td>N = 40</td>
</tr>
<tr>
<td><strong>μ or #</strong></td>
<td></td>
</tr>
<tr>
<td><strong>σ or %</strong></td>
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<tr>
<td><strong>μ or #</strong></td>
<td></td>
</tr>
<tr>
<td><strong>σ or %</strong></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>14.89</td>
</tr>
<tr>
<td>Male N, %</td>
<td>32</td>
</tr>
<tr>
<td>ADOS-CSS</td>
<td>8.15</td>
</tr>
<tr>
<td>IQ</td>
<td>100.78</td>
</tr>
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</table>

IQ is calculated averaging across participants per group.
Questions and Hypothesis

DANVA-2 faces

TD/ASD participants

EEG neural activity

Deep ConvNet

Blackbox?
Questions and Hypothesis

1. Are face emotion recognition (FER) deficits in ASD exhibited at the level of neural encoding?
   ○ Can Deep Learning successfully decode emotion recognition from neural activity elicited by the viewing of faces?

1. What is distinct about the way individuals with ASD are encoding emotions, when and where do they do so?
Emotion Decoding - Full Pipeline

EEG single-trial
752 time points x 30 channels EEG image

Artifact Removal

Whitening Normalization

752 time x 30 channels EEG whitened image

Deep ConvNet

Single trial EEG-based Emotion Classification

Max-pooling
Convolution

Argmax Adam Optimizer

4 class probabilities
-Happy
-Sad
-Angry
-Fear

Norm

Fully-connected

Norm

1024

1024

128

128

2

2

512

64

64

32

32

100

128

2

2
Performance Results - Sample #1 TD N=48, ASD N=40

FER and Deep ConvNet Accuracies TD N=48, ASD N=40, Sample #1

- FER
- Deep ConvNet [0-1500]ms

Accuracy

TD
ASD

Significance levels: *
***
Performance Results - Confusion Matrix FER/Deep ConvNet TD

Confusion Matrix FER Accuracies TD, N=48, sample #1

Confusion Matrix Deep ConvNet Accuracies TD N=48, Sample #1

FER Human Conf Matrix

Negative emotions

Deep ConvNet Machine Conf Matrix
Performance Results - Confusion Matrix FER/Deep ConvNet

**FER Human Conf Matrix**

**Deep ConvNet Machine Conf Matrix**

**Confusion Matrix FER Accuracies ASD, N=40, sample #1**

<table>
<thead>
<tr>
<th></th>
<th>Happy</th>
<th>Sad</th>
<th>Angry</th>
<th>Fear</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Happy</strong></td>
<td>0.94 (453)</td>
<td>0.04 (17)</td>
<td>0.17 (83)</td>
<td>0.16 (76)</td>
</tr>
<tr>
<td><strong>Sad</strong></td>
<td>0.03 (13)</td>
<td>0.86 (412)</td>
<td>0.13 (63)</td>
<td>0.06 (26)</td>
</tr>
<tr>
<td><strong>Angry</strong></td>
<td>0.01 (5)</td>
<td>0.05 (26)</td>
<td>0.63 (301)</td>
<td>0.05 (22)</td>
</tr>
<tr>
<td><strong>Fear</strong></td>
<td>0.02 (9)</td>
<td>0.05 (25)</td>
<td>0.07 (32)</td>
<td>0.74 (354)</td>
</tr>
</tbody>
</table>

**Confusion Matrix Deep ConvNet Accuracies ASD N=40, Sample #1**

<table>
<thead>
<tr>
<th></th>
<th>Happy</th>
<th>Sad</th>
<th>Angry</th>
<th>Fear</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Happy</strong></td>
<td>0.33 (444)</td>
<td>0.01 (7)</td>
<td>0.02 (6)</td>
<td>0.04 (19)</td>
</tr>
<tr>
<td><strong>Sad</strong></td>
<td>0.04 (9)</td>
<td>0.94 (451)</td>
<td>0.01 (4)</td>
<td>0.01 (6)</td>
</tr>
<tr>
<td><strong>Angry</strong></td>
<td>0.01 (5)</td>
<td>0.02 (10)</td>
<td>0.94 (453)</td>
<td>0.02 (10)</td>
</tr>
<tr>
<td><strong>Fear</strong></td>
<td>0.03 (9)</td>
<td>0.03 (12)</td>
<td>0.03 (15)</td>
<td>0.93 (445)</td>
</tr>
</tbody>
</table>
Performance Results - FER-Deep ConvNet intra-group

Variation Intragroup FER-Deep ConvNet Accuracies, Sample #1

Accuracy

TD

ASD

FER
Deep ConvNet
Performance Results - FER-Deep ConvNet-ADOS-CSS intra-group

Correlation between Accuracies (metrics) and ADOS-CSS, Sample #1
Can Deep Learning successfully decode emotion recognition from neural activity elicited by the viewing of faces? - answer question #1

- Deep ConvNets of EEG response in ASD and TD → similarly high performance in terms of correctly encoding FER
- ASD → significantly poorer behavioral performance on FER
  - Compared to TD
  - Compared to their own correct encoding
- ASD → DO encode FER correctly!
  - Do not reliably DEPLOY this information for FER judgement as expected
Questions and Hypothesis

1. Are face emotion recognition (FER) deficits in ASD exhibited at the level of neural encoding?
   ○ Can Deep Learning successfully decode emotion recognition from neural activity elicited by the viewing of faces?

1. What is distinct about the way individuals with ASD are encoding emotions, when and where do they do so?
LRP B Preset is the most reliable method included in iNNvestigate package (P.J. Kiendermans et. al 2017, Montavon et. al 2018)
Feature Importance Results - Average LRP B flat preset TD-ASD differences
Feature Importance Results - Average LRP B flat preset TD-ASD
What is distinct about the way individuals with ASD are encoding emotions, when and where do they do so? - Answer question #2

- Identified which time windows (and channels) are **most relevant** for accurate FER encoding in ASD and TD
- Temporal distribution is somewhat *later* for ASD
  - **consistent** with previous findings related to **altered networks** activation presented in ASD groups.
Overall Study Conclusions and Broader Implications

- Deep ConvNet: **effective perceptual classifier** from EEG data
  - can successfully complete FER from TD and ASD groups
- No difference between ASD and TD at the level of encoding FER information.
  - Despite difference in behavior!
  - Replicates in multiple datasets
  - FER behavioral deficits in ASD → translation, no encoding
- Relevance pattern using reliable saliency maps → altered post-cognitive neural activation in ASD groups
- Interventions need **not** teach encoding
  - Should focus on **gap** between encoding and behavior
Acknowledgements

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  - Association for Psychological Science