Some Effects of Specific Interest on the Brain of Children with Autism Spectrum Disorder (ASD): A Functional Near-infrared Spectroscopy Study

Huilin Zhu[1 *], **Yuebo Fan**[3], **Xinge Li**[1, 2], **Dan Huang**[3], **Huan Guo**[2], **and Sailing He**[1, 4]

[1]Centre for Optical and Electromagnetic Research, South China Academy of Advanced Optoelectronics
South China Normal University (SCNU), Guangzhou 510006, China
[2]School of Psychology, South China Normal University (SCNU), Guangzhou 510631, China
[3]Guangzhou Rehabilitation and Research Center for Children with ASD, Guangzhou 510540, China
[4]Department of Electromagnetic Engineering, Royal Institute of Technology, Stockholm 10044, Sweden

Abstract— Autism spectrum disorder (ASD) is a neuro-developmental disorder, characterized by two major domains: impairments in the social cognition and communication as well as restricted, repetitive, stereotyped interests and behaviors. In this study, functional near-infrared spectroscopy (fNIRS) was applied to investigate the atypical activation pattern of language areas (bilateral inferior frontal gyrus and bilateral temporal cortex) and uncover the impact of a specific interest on the brain function of children with ASD. We employed a listening comprehension task to stimulate the language areas of 2 ASD boys (A1 and A2) who had strong interests in the experiment material ("Lightning McQueen") and another 2 ASD boys (A3 and A4) who were matched with A1 and A2 respectively by age, intelligence quotient, language ability and the severity of symptoms. Our results showed that, during the task, the picture of "Lightning McQueen", but not the words of "The little red car", elicited stronger activation in the bilateral inferior frontal gyrus and temporal cortex of A1 and A2 than A3 and A4. These results could facilitate our understanding of language development of ASD and reconsider the role of specific interests (especially visual stimuli) played in the brain functional development of ASD.

1. INTRODUCTION

Functional near infrared spectroscopy (fNIRS) is an emerging non-invasive optical method for neuroimaging, which is increasingly applied to study infants, children, adolescents, adults and clinical populations, with the purpose of revealing typical and atypical developmental patterns of the brain [1]. Autism spectrum disorder (ASD) is a neurodevelopmental disorder, characterized by impaired social cognition and communication, rigid, repetitive, and stereotyped patterns of behavior and interests. Previous studies have demonstrated that adults and adolescents with ASD exhibited atypical activation and connectivity pattern in the language area of the brain [2, 3], including the bilateral inferior frontal gyrus (IFG) and temporal cortex (TC), which suggested the disrupted developmental pattern of language regions of ASD. However, IFG and TC were not only responsible for language processing but also contributed to social perception and cognition [4, 5]. Hence, in this study, we used fNIRS to measure the hemodynamic responses of IFG and TC when ASD children were performing a listening comprehension task and investigate how a specific interest in the task, as a social cognition component, could influence the activation pattern of IFG and TC. We hypothesized that a specific interest would improve the malfunction of language areas of children with ASD.

2. MATERIALS AND METHODS

2.1. Participants and Experiment Protocol

Participants were 4 children from 7 to 9 years of age who were diagnosed as ASD. All of the participants were boys and right-handed. During the listening comprehension task, children were asked to listen to a list of sentences and then answered the questions with two different types of promptings (pictures or words). There were 4 trials in each block and 2 blocks in the experiment. One block included the prompting of pictures of "Lightning McQueen" and another block included the prompting of words of "The little red car". All the trails in each block and all the blocks were presented by e-prime 2.0 randomly. The experiment protocol was approved by the Institutional Review Board of Guangzhou Rehabilitation and Research Center for Children with ASD.

*Corresponding author: Huilin Zhu (huilin.zhu@coer-scnu.org).

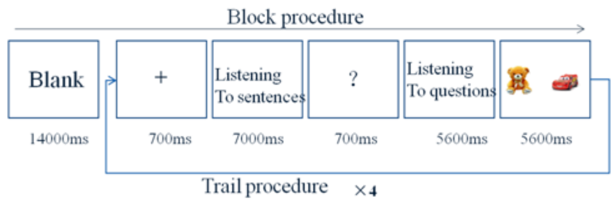

Figure 1: The block procedure (with the prompting of pictures).

Among the 4 children, 2 children with ASD (A1 and A2) showed strong interests in a cartoon character named "Lightning McQueen" which was one of the materials used in the experiment. A1 was preoccupied by "Lightning McQueen" and its relevant movies, games and pictures, whereas A2 was a car expert who knew "Lightning McQueen" very well, but his interest also extended to other cars, especially to red racing cars. Therefore, we compared the brain performances of A1 and A2 with another 2 ASD boys (A3 and A4) who were match with A1 and A2 respectively in age, intelligence quotient, language ability and the severity of symptoms.

2.2. NIRS Measurements

Measurements were performed with a fNIRS system (FOIRE-3000, Shimadzu Corporation, Kyoto, Japan) working at three wavelengths, 780 nm, 805 nm and 830 nm with a sampling rate of 14.286 Hz (time resolution = 70 ms). The distance between the emitter and detector was fixed at 3 cm. The measured brain regions and channel configurations were shown in Figure 2.

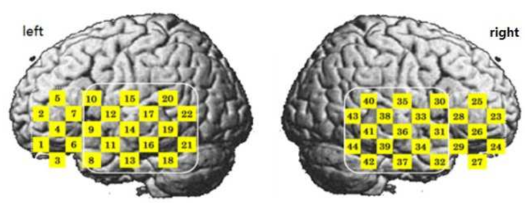

Figure 2: Channel configurations in IFG and TC. There were 14 channels (left hemisphere: from Channel 1 to Channel 7, right hemisphere: from Channel 23 to Channel 29) covering IFG and 30 channels (left hemisphere: from Channel 8 to Channel 22, right hemisphere: from Channel 30 to Channel 44) covering TC. We used international 10-10 system to locate: Channel 4 and 26 were located in F7 and F8; Channel 9 and 31 were located in the FT7 and FT8.

2.3. Data Analysis

Only HbO data was included in analysis. We used NIRS-SPM [6] to preprocess and statistically analysis the data and define the spatial correlates underlying the different conditions. For each participant, the raw time course data were preprocessed to remove sources of noises and artifacts by the hemodynamic response function (hrf) and wavelet-MDL detrending algorithm (wavelet-MDL). Then, we performed a general linear model (GLM) to test the effect of different promptings by convolving the task with the hemodynamic response function (without time or dispersion derivatives) and computing parameter estimates (beta values of the GLM as the weights). The F contrasts were calculated for one-way comparison: promptings (pictures and words) at each channel. To control for false positives caused by multiple comparisons, all p values were corrected by false discovery rate. The significant channels were mapped onto the corresponding location of the cortex.

3. RESULTS

We analyzed and compared the brain activation (HbO) between A1 and A3, as well as between A2 and A4, who were matched in pairs with age, intelligence quotient, language ability and the severity of ASD symptoms respectively. Compared to A3 and A4, A1 and A2 were very interested in "Lightning McQueen". As the statistical parametric mapping shown in Figure 3, A1 and A2 showed significant stronger activation in the bilateral IFC and bilateral TC than A3 and A4 when performing the listening comprehension task under the prompting of the pictures (with visual stimuli of "Lightning McQueen"). In particular, for A1 who was preoccupied by "Lightning McQueen", there

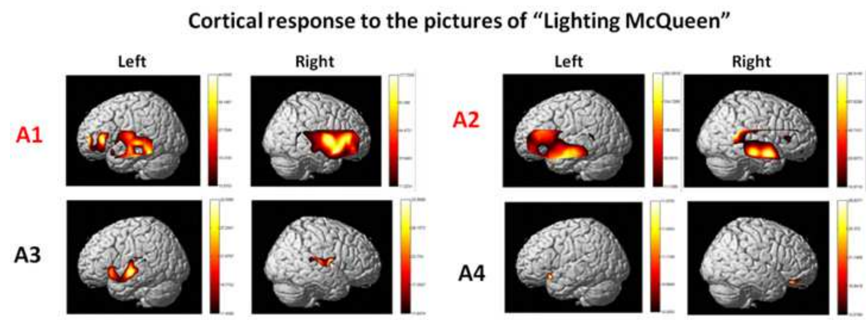

Figure 3: The statistical parametric mapping of all the children with ASD. The regions with color were statistically significant channels by general linear model analysis ($P_{FDR} < 0.05$). There were obvious activation of IFG and TC to experiment condition with the pictures of "Lightning McQueen" in A1 and A2 but not in A3 and A4.

was more activation in the bilateral IFC and bilateral TC to the pictures of "Lightning McQueen" than A3.

4. DISCUSSION

In the present study, we employed fNIRS to detect the activation pattern in IFG and TC under listening comprehension task and reveal the effect of a specific interest on brain function of children with ASD. Previous studies have demonstrated the language areas, such as Broca's area (left IFG) and Wernicke's area (left superior TC) were significantly less activated in adolescents and adults with ASD underlying language and communication defects. However, we observed that 2 children with ASD, named A1 and A2, who were very interested in one of the materials in the experiment ("Lightning McQueen"), exhibited pronouncedly stronger activation in the bilateral IFG and bilateral TC than A3 and A4 children, who did not show any interests in the experiment stimuli. In line with another study with functional magnetic resonance imaging [7], our results implicated that a specific interest may play an important role in the functional development of brain language areas of children with ASD. Furthermore, the visual preference of participants with ASD was also observed in our results. Previous fMRI studies have indicated that participants with ASD prefer to use visual coding strategy rather than verbal coding strategy during language processing [8]. We found that, although A1 had a restricted interest in the pictures of "Lightning McQueen" whereas A3 had extended interests in both the pictures of "Lightning McQueen" and the words of "The little car", they consistently exhibited stronger activation in the bilateral IFG and bilateral TC to the pictures of "Lightning McQueen" than to the words of "The little car", which suggested that there was enhanced visual processing in domains such as language in ASD.

5. CONCLUSION

In summary, by using fNIRS to investigate how a specific interest could affect the atypical brain function of language areas of children with ASD, we mainly found, 2 ASD children showed pronounced stronger activation in the bilateral inferior frontal gyrus and temporal cortex in response to their favorite cartoon character than matched ASD children. Our results implied that specific interests in visual stimuli, like some pictures of favorite cartoon character, could have a positive effect on improving the atypical brain function of children with ASD underlying social cognition and language impairments. Additionally, our study also suggests that fNIRS is a feasible and effective technique to monitor the brain activity of awoken children with autism spectrum disorder.

ACKNOWLEDGMENT

This work was supported by Guangdong Innovative Research Team Program (No. 2010 01D0104799 318), the Natural Science Foundation of Guangdong province (2014A030310502).

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