Parent training effects on emotion recognition in mothers rearing children with attention-deficit/hyperactivity disorder: A randomized controlled functional magnetic resonance imaging study

Kai Makita (kai@u-fukui.ac.jp)
University of Fukui: Fukui Daigaku
https://orcid.org/0000-0002-7699-9485

Akiko Yao
University of Fukui: Fukui Daigaku

Koji Shimada
University of Fukui: Fukui Daigaku

Ryoko Kasaba
University of Fukui: Fukui Daigaku

Takashi X Fujisawa
University of Fukui: Fukui Daigaku

Yoshifumi Mizuno
University of Fukui: Fukui Daigaku

Akemi Tomoda
University of Fukui: Fukui Daigaku

Research Article

Keywords: Emotion recognition, MRI, Parent training, Stress, ADHD

Posted Date: February 11th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1304879/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

This randomized controlled study aimed to examine neurological changes in socioemotional processing skills through parent training in caregivers of children with attention-deficit/hyperactivity disorder. Thirty mothers of children with ADHD were stratified into parental training and non-parental training groups. Functional magnetic resonance imaging was performed during the ‘Reading the Mind in the Eyes’ test, and parenting difficulties were evaluated using the Parenting Stress Index and Parenting Scale twice—before and after parental training. Parenting Stress Index and Parenting Scale scores significantly decreased after parental training. Activity in the left occipital fusiform gyrus increased during the task to estimate emotions from facial pictures, with decreased response time only seen after parental training. Therefore, brain activity changes and enhanced responses after parental training might reflect an increased sensitivity and responsibility to others’ mental state. The present results suggest that parental training promotes mothers’ understanding of problematic behavior in children with attention-deficit/hyperactivity disorder, which could help build a more nurturing environment, reduce parenting stress and a maladaptive parenting style, and improve the mother-child relationship.

Introduction

There is a strong link between developmental disabilities in children and parenting difficulties (Woodman et al., 2015). Attention-deficit/hyperactivity disorder (ADHD), one of the most commonly diagnosed neurodevelopmental disorders in childhood, has a relatively high incidence (approximately 5%) (American Psychiatric Association, 2013). Children with ADHD have functional problems in social and academic areas (Marshall et al., 2014). In addition, ADHD symptoms in children can negatively affect the caregivers' psychological state, parenting behavior, and parent-child relationships (Hutchison et al., 2016; Pelham et al., 1998). These negative influences could result in inappropriate parental responses, such as maltreatment, creating risk factors for the later development of conduct problems in the affected children (Chronics-Tuscano et al., 2008; Chronis et al., 2007).

Parent training (PT) is a psychosocial and support intervention that promotes a nurturing environment for child care (parental understanding and response), widely known for its effectiveness (Daley et al., 2014) and recommended for parents of children with ADHD (Posner et al., 2020). The PT program for ADHD includes essential information for parents on the characteristics of the disability and treatment options (Iwasaka, 2012; Zwi et al., 2011). Studies using PT for mothers rearing ADHD children have reported that PT significantly improved their stress and parenting self-efficacy and style (reduced overly harsh responses, lack of consistency, and ineffective limit-setting) (Abikoff et al., 2015; Heath et al., 2015; Shimabukuro et al., 2017). Such positive maternal attitudes reduce problematic behaviors (Smith et al., 2008) and prevent behavioral problems in children with ADHD (Tully et al., 2004). However, these previous studies have focused on questionnaire data, and only a few have examined the effectiveness of PT using more quantitative indicators (e.g., neuroimaging data).

A previous neuroimaging study reported that tasks that measure social skills and abilities, such as mind reading tasks (“Reading the mind in the eyes task [RMET] (Baron-Cohen et al., 2001), are negatively influenced by stress (Nolte et al., 2013) or depressive symptoms and may, therefore, be useful biomarkers of caregivers’ depression/stress (Shimada et al., 2018). In the RMET, participants evaluate the mental states of others from static images of the eye region. Previous functional magnetic resonance (fMRI) studies using the RMET have reported the involvement of the inferior frontal gyrus, supplemental motor area, inferior temporal gyrus, fusiform gyrus, and occipital gyrus during mental state judgement (Adams et al., 2010; Baron-Cohen et al., 2006; Castelli et al., 2010; Focquaert et al., 2010; Shimada et al., 2018). However, it is unclear whether improving a caregiver's stress by PT also improves the activation of these areas.

Herein, we focused on the effects of PT on parenting stress in mothers of children with ADHD and examined its effects at the neurological level. We hypothesized that PT would improve qualitative stress and unsound parenting practice index, as determined using parenting stress and discipline questionnaires. Moreover, we hypothesized that functional changes in the brains of mothers, especially in the regions involved in judging other's mental status, could be revealed by blood oxygenation level-dependent (BOLD) fMRI during the RMET. Understanding the effects of PT at a functional neural level could potentially aid the development of more precise treatment strategies and biomarkers that could evaluate treatment effects.

Methods

Participants

Thirty mothers (mean age=38.72 years; standard deviation [SD]=4.46 years) agreed to participate in this study. The inclusion criteria were as follows: mothers caring for ≥1 school-aged child (6~12 years old) diagnosed with ADHD in hospitals or pediatric clinics.
diagnosis of ADHD was performed using the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (American Psychiatric Association, 2013). The exclusion criteria were as follows: mothers who had participated in other PT programs within two months before the time of enrolment, and changes in the child's medication status during the study.

All participants had normal or corrected-to-normal vision with no known medical, neurological, or psychiatric history (based on self-report questionnaires) and met the safety requirements for participation in an MRI study. The Ethics Committee of the University of Fukui approved the study protocol; all procedures were conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent.

**Study design**

Using a permuted-block randomization procedure as a computer-based random number generator, mothers were randomly allocated to two groups: mothers who attended a 13-week PT session (PT group), and mothers who did not attend such a session until the end of the study (non-PT group). In the PT group, mothers were taught and trained on the following contents by two trained clinical psychologists throughout the 13-week sessions: sufficient knowledge of ADHD, psychological support, helpful strategies to modify children's behavior regarding ADHD, and effective methods to improve the parent-child relationship (Supplementary Material 1, Parent training). Before and after PT (approximately 90 days apart), mothers in both groups participated twice in the experiments (baseline [Time 1] and post-baseline [Time 2]). In the experiment, the participants' psychological characteristics were measured using psychological questionnaires, and their brain activities during emotion/gender judgement were examined using fMRI. Among the participants (30 mother-child dyads), the data of seven mothers did not reach postbaseline evaluations; thus, the efficacy analysis included 13 dyads who received PT and 10 dyads who did not (Figure 1).

--- Figure 1 insert around here

**Questionnaires for psychological testing**

The Interpersonal Reactivity Index (IRI) (Davis, 1983; Sakurai, 1988), which comprises four subscales (empathic concern, personal distress, perspective taking, and fantasy), was used to measure the mothers' empathic abilities, and the Beck Depression Inventory-II (BDI-II) (Beck et al., 1996; Kojima et al., 2002) was used to measure the mothers' current depression. To measure maternal parenting stress, we used the Parental Stress Index (PSI) (Abidin, 1995; Narama et al., 1999), which includes the child and parent stressor domains. In both domains, higher scores indicate that the rater scored the child's behavior more negatively or that the rater negatively assessed themselves or the surrounding environment in parenting. The Parenting Scale (PS) (Arnold et al. 1993; Itani 2010) was used to examine the mothers' parenting disciplines in laxness and overreactivity; this refers to the tendency to respond permissively (by passive and inconsistent parenting practices) or harshly (by overly authoritarian parenting practices), respectively, to child misbehavior. During the study, the BDHI, PSI, and PS scores were measured twice (Time 1 and Time 2), and used to assess the effects of PT.

**Task and procedures**

In the MRI study, mothers completed the revised RMET version (Baron-Cohen et al., 2001; Shimada et al., 2018). The task consisted of 36 trials. In each trial, the participant was presented with a black and white photograph showing the eye region of a human face with two words placed below (one of which correctly identified the person's mindset or gender). The participants were asked to indicate the word they felt best described what the person in the photograph was thinking or feeling (in this study "ToM" condition) or the gender (male or female) depicted (in this study "GeN" condition) by pressing one of two buttons in the scanner (Current Design, Philadelphia, USA). The task was run using Presentation software (Neurobehavioral Systems, Albany, CA, USA), and projected using an MRI-compatible LCD display (BOLDscreen, Cambridge Research System, UK) placed on the back of the scanner. The participants viewed the stimuli via a mirror attached to the head coil.

**fMRI acquisition and analyses**

A 3-T MRI scanner (Signa PET/MR, ver. 26, GE Healthcare, Milwaukee, WI, USA) with a standard 8-channel head coil was used to scan participants. Functional images were corrected with a T2*-weighted gradient-echo echo-planar imaging sequence to produce 40 whole-brain, continuous, transaxial slices (slice thickness = 3.0 mm with 0.5 mm gap, repetition time [TR] = 2500 ms; echo time [TE] = 25 ms; flip angle [FA] = 80°; field of view [FOV] = 192 mm; 64 × 64 matrix; voxel dimension = 3.0 × 3.0 mm). A T1-weighted anatomical scan was also acquired using a fast spoiledgradient recalled imaging sequence (TR = 8.46 ms; TE = 3.24 ms; FA = 11°; FOV = 256 mm; 256 × 256 matrix; 172 slices; voxel dimension = 1.0 × 1.0 × 1.0 mm).
In the imaging data processing, for MRI signal equilibrium, the first four volumes were discarded from the analysis. The remaining 240 images were preprocessed and analysed using the Statistical Parametric Mapping software (SPM ver.12, Wellcome Trust Center for Neuroimaging, London, UK) implemented in MATLAB R2019b (MathWorks, Natick, USA). Following slice timing correction and spatial realignment, T1-weighted anatomical images were co-registered to functional images and segmented using a new segmentation algorithm with diffeomorphic anatomical registration through the exponentiated lie algebra (DARTEL) technique (Ashburner, 2007). Functional images were then spatially normalized into the Montreal Neurological Institute template, re-sampled into a spatial resolution of $3 \times 3 \times 3$ mm$^3$, and spatially smoothed with a 6 mm full width at half-maximum Gaussian kernel.

After MRI data pre-processing, we first performed individual analyses to identify task-related activity. In this analysis, a design matrix containing two regressors of interest (ToM and GeN conditions) and six motion parameters, as nuisance regressors, was created. Then, two contrast images (ToM and GeN) were obtained for each participant. Brain activation during each condition was modelled with a general linear model, by using a box-car function convolved with the canonical hemodynamic response function.

For group analyses, the two contrast images corresponding to the ToM and GeN conditions generated in the individual analyses were chosen. To investigate the effect of PT, between- and within-group differences (PT/non-PT vs. [Time 1/Time 2]) were analysed in the framework of the SPM flexible factorial design. In this analysis, to depict the regions showing the PT effect on the PT group compared with that on the non-PT group (regions showing a significant decrease and/or increase after the PT intervention period), the contrast of interest was set as follows: PT (Time 1>Time 2) > non-PT (Time 1>Time 2) and PT (Time 2>Time 1) > non-PT (Time 2>Time 1). These comparisons were performed separately for both ToM and GeN conditions. Subsequently, to identify the expected intervention effect in the PT group, we conducted an SPM one-way analysis of variance (ANOVA) with a within-subject design to compare separately the activities within the PT and non-PT groups under both conditions. The statistical threshold was set at $p<0.005$, uncorrected at the peak level, and at $p<0.05$ at the cluster level, family-wise error-corrected for multiple comparisons over the whole brain. The Neuromorphometrics atlas (http://www.neuromorphometrics.com/) was used to identify the anatomical localization of significant clusters.

**Questionnaires and behavioral task data analyses**

Fisher’s exact tests and individual $t$-tests were performed to compare the clinical and demographic characteristics between groups. Questionnaire scores and behavioral performance during the RMET were compared using mixed-model repeated measures ANOVAs with time as the within-subject factor (pre- and post-PT duration: Time 1 & Time 2, and groups as the between-group factor (PT and non-PT). For the RMET performance, the intervention effects were assessed on reaction times (RTs) and correct answer rate (accuracy) separately for the ToM and GeN conditions. To further investigate significant effects, Bonferroni-corrected pair-wise comparisons were performed. Statistical analyses were performed using IBM SPSS version 24 (IBM Corp., Armonk, NY, USA).

**Results**

**Demographics and assessment outcomes at Time 1**

There were no significant differences between the PT and non-PT groups regarding age; BDI-II, STAI, PSI, PS, and IRI scores; years of education; and handedness at Time 1 (Table 1; Supplementary Material 2, Table S1, children’s data in both groups).
### Table 1
Demographics and psychological questionnaire scores of the PT and nonPT groups at baseline (Time 1)

|                  | PT group (n=13) | non-PT group (n = 10) | Statistics       | p-value |
|------------------|-----------------|-----------------------|------------------|---------|
| **Mean (SD)**    |                 |                       |                  |         |
| Age (years)      | 38.5 (5.1)      | 40.1 (4.6)            | t-test [t(21)]   | 0.44    |
| BDI-II           | 11.6 (7.5)      | 9.6 (7.2)             | 0.65             | 0.52    |
| PSI              |                 |                       |                  |         |
| Child domain     | 109.2 (9.1)     | 103.7 (12.4)          | 1.22             | 0.24    |
| Parent domain    | 111.7 (21.2)    | 103.1 (21.0)          | 0.97             | 0.34    |
| PS               |                 |                       |                  |         |
| Laxness          | 22.7 (6.3)      | 21.6 (5.2)            | 0.44             | 0.66    |
| Overreactivity   | 40.5 (11.5)     | 41.7 (9.6)            | -0.28            | 0.79    |
| IRI              |                 |                       |                  |         |
| Empathic concern | 11.6 (2.1)      | 12.0 (2.3)            | -0.42            | 0.68    |
| Personal distress| 12.6 (3.3)      | 11.9 (2.6)            | 0.56             | 0.58    |
| Perspective taking | 14.8 (2.0)    | 16.2 (2.5)            | -1.52            | 0.15    |
| Fantasy          | 12.4 (3.4)      | 11.8 (2.3)            | 0.47             | 0.64    |
| **n (%)**        |                 |                       | Fisher's exact test |       |
| Completed ≥12 years of education | 13 (100) | 10 (100) | NA | |
| Right handedness | 12 (92)         | 8 (80)                | 0.56             |         |

Notes: PT group, mothers planned to be enrolled in the parent training intervention; non-PT group, mothers who were not enrolled in the parent training intervention after the end of the study. Abbreviations: BDI-II, Beck Depression Inventory-II; IRI, Interpersonal Reactivity Index; NA, not applicable; PS, Parenting Scale; PSI, Parenting Stress Index; PT, parent training; SD, standard deviation; STAI, State-Trait Anxiety Inventory.

---

**Changes in questionnaire scores and RMET performance between Time 1 and Time 2**

After the PT intervention period (Time 2), 2 × 2 ANOVAs (Time [Time 1, Time 2] × Group [PT, non-PT]) showed no significant main effects of interactions for the BDI-II scores. For PSI child domain scores, there was a significant Time × Group interaction (F (1, 21)=10.076, p=0.005), while the post-hoc within group t-test showed significantly lower scores after PT than before (p=0.003, 95% confidence interval [CI]: 14.376, -3.470) in the PT group, but not in the non-PT group. For PSI parent domain scores, we also found a significant Time × Group interaction (F (1, 21)=8.804, p=0.007) at Time 2, with a significant decrease in the PT group (p=0.042, 95% CI: -12.683, -0.240), and a marginally significant increase in the non-PT group (p=0.053, 95% CI: -0.093, 14.093). For PS overreactivity scores, there was a significant Time × Group interaction (F (1, 21)=4.611, p=0.044), with a significant decrease in the PT group (p=0.009, 95% CI: -11.415, -1.816), but no significant differences in the non-PT group. No significant main effects or interactions were found for laxness scores.

Regarding RMET performance, in the ToM condition, the RTs showed a marginally significant interaction of Time × Group (F (1, 21)=4.323, p=0.050), with a significant decrease in RTs in the PT group (p=0.005, 95% CI: 313.925, -61.642) but not in the non-PT group. The other indices (RTs in GeN condition, accuracy in the ToM condition or GeN condition) showed no significant main effects or interactions (Table 2).
## Table 2

**Psychological questionnaire scores of outcome measures in the PT and non-PT groups at baseline (Time 1) and in the post-intervention period (Time 2)**

|                        | PT group (n = 13) | Statistics | non-PT group (n = 10) | Statistics | Statistics |
|------------------------|-------------------|------------|-----------------------|------------|------------|
|                        | Time 1            | Time 2     | Paired t-test         | Time 1     | Time 2     | Paired t-test | ANOVA (Group x Time interaction) |
| Mean (SD)              | Mean (SD)         | p-value    | 95% CI                | Mean (SD)  | Mean (SD)  | p-value    | 95% CI | F-value | p-value | Partial η² |
| BDHI                   | 11.62 (7.50)      | 8.23 (7.26) | 0.079                 | -7.20 - 0.43 | 9.6 (7.2)  | 0.81       | -4.85 - 3.85 | 1.08 | 0.310 | 0.09  |
| PSI                    |                   |            |                       |            |            |            |         |         |         |         |
| Child domain           | 109.15 (9.05)     | 100.23 (12.47) | 0.003*              | -14.38 - 3.47 | 103.70 (12.41) | 107.40 (13.08) | 0.23 | -2.52 - 9.92 | 10.08 | 0.005* | 0.32 |
| Parent domain          | 111.69 (21.20)    | 105.23 (21.21) | 0.042*              | -12.68 - 0.24 | 103.10 (21.00) | 110.10 (15.72) | 0.053 | -0.09 - 14.09 | 8.80 | 0.007* | 0.30 |
| PS                    |                   |            |                       |            |            |            |         |         |         |         |
| Laxness               | 22.69 (6.29)      | 22.84 (7.67) | 0.93                  | -3.24 - 3.55 | 21.60 (5.19)  | 22.70 (5.87)  | 0.56  | -2.77 - 4.97 | 0.15 | 0.71   | 0.01  |
| Overreactivity         | 40.46 (11.48)     | 33.85 (8.36) | 0.009*               | -11.42 - 1.82 | 41.70 (9.63)  | 42.60 (8.93)  | 0.75   | -4.57 - 6.37 | 4.61 | 0.044* | 0.18  |
| RMET                   |                   |            |                       |            |            |            |         |         |         |         |
| ToM                   |                   |            |                       |            |            |            |         |         |         |         |
| RTs                   | 2474.61 (339.63)  | 2286.83 (372.36) | 0.005*            | -313.93 - 61.64 | 2288.29 (351.48) | 2291.78 (384.43) | 0.96   | -140.34 - 147.31 | 4.32 | 0.050 | 0.17  |
| Accuracy              | 86.33 (5.37)      | 83.97 (7.45) | 0.25                  | -6.52 - 1.81 | 87.50 (6.18)  | 83.89 (5.52)  | 0.13   | -8.36 - 1.14 | 0.17 | 0.68   | 0.01  |
| GeN                   |                   |            |                       |            |            |            |         |         |         |         |
| RTs                   | 1191.53 (315.97)  | 1110.29 (191.48) | 0.29                | -236.31 - 73.82 | 1077.19 (243.66) | 1012.71 (264.62) | 0.46   | -240.86 - 112.74 | 0.22 | 0.88   | 0.001 |
| Accuracy              | 95.51 (4.0)       | 95.72 (3.87) | 0.84                  | -1.96 - 2.38 | 96.94 (3.06)  | 94.72 (4.43)  | 0.08   | -4.70 - 2.37 | 2.37 | 0.14   | 0.10  |

Notes: Accuracy, correct answer rate (%); PT group, mothers planned to be enrolled in the parent training intervention; non-PT group, mothers who were not enrolled in the parent training intervention after the end of the study.

Abbreviations: BDHI, Beck Depression Inventory-II; GeN, gender judgement condition; PS, Parenting Scale; PSI, Parenting Stress Index; PT, parent training; RMET, Reading the Mind in the Eyes Test; RTs, Reaction Times (msec); ToM, Theory of Mind condition; SD, standard deviation. *p < 0.05.

---

### Imaging results

Regarding the between- and within-group differences of the regional brain activation ([PT/nonPT] vs. [Time 1/Time 2]), there were no regions with significant changes in activity in the PT group compared to the non-PT group at Time 2. However, within-group comparisons indicated significantly increased activation in the left occipital fusiform gyrus in the PT group during the ToM condition at Time 2 (Figure 2, Table 3), whereas no such difference was found in the non-PT group. Given the few studies investigating the intervention effect of PT on brain function in mothers caring for children with ADHD, and to control the balance between Type I and II error risks, we explored the potential effects of PT by using p<0.005, uncorrected with a cluster size of k ≥40 voxels (Lieberman & Cunningham, 2009; Nishiyama et
We observed bilateral clusters of increased activation in the calcarine cortex, left inferior temporal gyrus, and right inferior occipital gyrus (Supplementary Material 3, Table S2). Other tests did not show any significant differences.

### Table 3

#### ToM condition

| Anatomical region       | Side  | MNI coordinates | Cluster | Voxel | Cluster Size | T value | P value |
|-------------------------|-------|-----------------|---------|-------|--------------|---------|---------|
|                          |       | x    | y    | z    |              |         |         |
| Time 1 > Time 2         | [No significant activations] |       |       |       |              |         |         |
| Time 2 > Time 1         |       | -24  | -93  | -15  | 193          | 5.43    | 0.028   |

#### GeN condition

|                          |       |       |       |       |              |         |         |
| Time 1 > Time 2         | [No significant activations] |       |       |       |              |         |         |
| Time 2 > Time 1         | [No significant activations] |       |       |       |              |         |         |

Notes: The threshold was set at $p < 0.005$, uncorrected at the peak level and $p < 0.05$, family-wise error-corrected for multiple comparisons at the cluster level. Locations were defined using the SPM neuromorphometrics atlas.

Abbreviations: GeN, Gender; MNI, Montreal Neurologic Institute; PT, parent training; ToM, Theory of Mind.

---

**Discussion**

In our study, mothers enrolled in the PT program exhibited less parenting stress as measured by the PSI, including both the child and parent domains. PS scores revealed that mothers in the PT group adopted fewer inappropriate parenting practices with respect to overreactivity. These results suggest that PT promotes the mothers’ understanding of the behavior in children with ADHD, thus reducing their stress and improving parenting disciplines. Our findings are in-line with those of previous studies using PT for mothers with ADHD children, showing decreased maternal stress and enhanced positive parenting practices after PT (Chronis-Tuscano et al., 2013; Heath et al., 2015; Shimabukuro et al., 2017). Although the Time × Group interaction remained marginally significant, the behavioral performance in the RMET showed reduced RTs in the PT group, only for the ToM condition.

Regarding the changes in regional brain activation, within-group comparisons showed significantly increased activation in the occipital part of the fusiform gyrus during others’ mental state judgement from facial features only in the PT group during the ToM condition. Using a more lenient threshold, we observed increased activation in temporal to occipital regions at Time 2 in the PT group compared with the nonPT group. Other neuroimaging studies using RMET produced similar results (Adams et al., 2010; Castelli et al., 2010; Schmidt et al., 2020). Since the fusiform gyrus is involved in the perception of emotions in facial expressions (Haxby et al., 2002; Mier et al., 2010), the changes in brain activity in the PT group might reflect their increased sensitivity to the other's mental states.

Altogether, our findings suggest that PT interventions in mothers provide them with a better understanding of their children, helping to create a more nurturing environment, and reducing parenting stress, subsequently improving activation in the fusiform gyrus during socioemotional processing.

This study has some limitations. First, it included a relatively small sample size and lacked a control group comprising mothers of typically developed children. Second, as all psychometric measures were self-reported, subjective bias might be present. Lastly, because
of the single-center study design, the participants’ demographic variability might be limited. Future research to address these limitations is warranted.

**Conclusions**

In summary, our findings suggest that PT promotes mothers’ understanding of problematic behavior in children with ADHD and might enhance mothers’ ability to process socioemotional information (recognize other’s emotional expression), which could help build a more nurturing environment, reduce parenting stress and maladaptive parenting style, and improve the mother-child relationship.

**Declarations**

**Acknowledgments**

The authors would like to thank all the mothers and their children who generously and courageously participated in this research. We also thank Editage [http://www.editage.com] for editing and reviewing this manuscript.

**Funding**

This research was supported by funds from the Japan Science and Technology Corporation (JST) and Research Institute of Science and Technology for Society (RISTEX).

**Conflicts of Interest**

The authors declare that they have no conflict of interest.

**Ethical approval**

The research protocol was approved by the Ethics Committee of the University of Fukui.

**Consent to participate**

Written informed consent was obtained from all participants.

**Consent for publication**

All authors have approved the manuscript for publication.

**Availability of data and material**

The dataset used for the current study is not publicly available due to the privacy act statement. Regarding questions about this data, readers may contact Professor Akemi Tomoda (atomoda@u-fukui.ac.jp).

**Code availability**

Not applicable.

**Author Contributions**

AT conceived the project. KM, AY, KS, RK, and AT designed the experiments. KM, AY, RK, KS, TF, and AT performed the experiments, collected the data, and analyzed the data. KM, YM, and AT wrote the manuscript. All authors have read and approved the final manuscript.

**Funding Sources**

This research was supported by funds from a Grant-in-Aid for Young Scientists (JP18K13107 to KM) and Challenging Exploratory Research (JP19K21755 to AT), and Grant-in-Aid for “Creating a Safe and Secure Living Environment in the Changing Public and Private Spheres” from the Japan Science and Technology Corporation (JST)/Research Institute of Science and Technology for Society (RISTEX) to AT.

**Compliance with Ethical Standards**
The Ethics Committee of the University of Fukui have reviewed and approved the study protocol, and written informed consent was obtained from all participants.

**Conflict of Interest**

All authors declare that they have no conflict of interest.

**Research Data Policy and Data Availability Statements**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

**References**

1. Abidin, R. R. (1995). *Parenting Stress Index: Professional manual*. Psychological Assessment Resources

2. Abikoff, H. B., Thompson, M., Laver-Bradbury, C., Long, N., Forehand, R. L., Miller Brotman, L., Klein, R. G., Reiss, P., Huo, L., & Sonuga-Barke, E. (2015). Parent training for preschool ADHD: A randomized controlled trial of specialized and generic programs. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 56*(6), 618–631. https://doi.org/10.1111/jcpp.12346

3. Adams, R. B., Rule, N. O., Franklin, R. G., Wang, E., Stevenson, M. T., Yoshikawa, S., Nomura, M., Sato, W., Kveraga, K., & Ambady, N. (2010). Cross-cultural reading the mind in the eyes: An fMRI investigation. *Journal of Cognitive Neuroscience, 22*(1), 97–108. https://doi.org/10.1162/jocn.2009.21187

4. American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. Washington DC: American Psychiatric Association

5. Arnold, D. S., O'Leary, S. G., Wolff, L. S., & Acker, M. M. (1993). The Parenting Scale: A measure of dysfunctional parenting in discipline situations. *Psychological Assessment, 5*(2), 137–144. https://doi.org/10.1037/1040-3590.5.2.137

6. Ashburner, J. (2007). A fast diffeomorphic image registration algorithm. *NeuroImage, 38*(1), 95–113. https://doi.org/10.1016/j.neuroimage.2007.07.007

7. Baron-Cohen, S., Ring, H., Chitnis, X., Wheelwright, S., Gregory, L., Williams, S., Brramer, M., & Bullmore, E. (2006). fMRI of parents of children with Asperger syndrome: A pilot study. *Brain and Cognition, 61*(1), 122–130. https://doi.org/10.1016/j.bandc.2005.12.011

8. Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The “Reading the Mind in the Eyes” Test (rev. version): a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 42*(2), 241–251

9. Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the beck depression inventory-II*. San Antonio, TX: Psychological Corporation

10. Castelli, I., Baglio, F., Blasi, V., Alberoni, M., Falini, A., Liverta-Sempio, O., Nemni, R., & Marchetti, A. (2010). Effects of aging on mindreading ability through the eyes: An fMRI study. *Neuropsychologia, 48*(9), 2586–2594. https://doi.org/10.1016/j.neuropsychologia.2010.05.005

11. Chronis, A. M., Lahey, B. B., Pelham, W. E., Williams, S. H., Baumann, B. L., Kipp, H., Jones, H. A., & Rathouz, P. J. (2007). Maternal depression and early positive parenting predict future conduct problems in young children with attention-deficit/hyperactivity disorder. *Developmental Psychology, 43*(1), 70–82. https://doi.org/10.1037/0012-1649.43.1.70

12. Chronis-Tuscano, A., Clarke, T. L., O’Brien, K. A., Raggi, V. L., Diaz, Y., Mintz, A. D., Rooney, M. E., Knight, L. A., Seymour, K. E., Thomas, S. R., Seeley, J., Kosty, D., & Lewinsohn, P. (2013). Development and preliminary evaluation of an integrated treatment targeting parenting and depressive symptoms in mothers of children with attention-deficit/hyperactivity disorder. *Journal of Consulting and Clinical Psychology, 81*(5), 918–925. https://doi.org/10.1037/a0032112

13. Chronis-Tuscano, A., Raggi, V. L., Clarke, T. L., Rooney, M. E., Diaz, Y., & Pian, J. (2008). Associations between maternal attention-deficit/hyperactivity disorder symptoms and parenting. *Journal of Abnormal Child Psychology, 36*(8), 1237–1250. https://doi.org/10.1007/s10802-008-9246-4

14. Daley, D., van der Oord, S., Ferrin, M., Danckaerts, M., Doepfner, M., Cortese, S., Sonuga-Barke, E. J. S., & European ADHD Guidelines Group. (2014). Behavioral interventions in attention-deficit/hyperactivity disorder: A meta-analysis of randomized controlled trials across multiple outcome domains. *Journal of the American Academy of Child and Adolescent Psychiatry, 53*(8), 835–47, 847.e1, 847.e1–5. https://doi.org/10.1016/j.jaac.2014.05.013
15. Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology, 44*(1), 113–126. https://doi.org/10.1037/0022-3514.44.1.113

16. Focquaert, F., Steven-Wheeler, M. S., Vanneste, S., Doron, K. W., & Platek, S. M. (2010). Mindreading in individuals with an empathizing versus systemizing cognitive style: An fMRI study. *Brain Research Bulletin, 83*(5), 214–222. https://doi.org/10.1016/j.brainresbull.2010.08.008

17. Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry, 51*(1), 59–67. https://doi.org/10.1016/s0006-3223(01)01330-0

18. Heath, C. L., Curtis, D. F., Fan, W., & McPherson, R. (2015). The association between parenting stress, parenting self-efficacy, and the clinical significance of child ADHD symptom change following behavior therapy. *Child Psychiatry and Human Development, 46*(1), 118–129. https://doi.org/10.1007/s10578-014-0458-2

19. Hutchison, L., Feder, M., Abar, B., & Winsler, A. (2016). Relations between parenting stress, parenting style, and child executive functioning for children with ADHD or autism. *Journal of Child and Family Studies, 25*(12), 3644–3656. https://doi.org/10.1007/s10826-016-0518-2

20. Itani, T. (2010). The Japanese version of the Parenting Scale: Factor structure and psychometric properties. *Shinrigaku Kenkyu: The Japanese Journal of Psychology, 81*(5), 446–452. https://doi.org/10.4992/jjpsy.81.446

21. Iwasaka, H. Ed. (2012). Pearento Torëningu Gaidobukku (Parent Training Guidebook). Jihou Inc, Tokyo, Japan. (In Japanese).

22. Kojima, M., Furukawa, T. A., Takahashi, H., Kawai, M., Nagaya, T., & Tokudome, S. (2002). Cross-cultural validation of the Beck Depression Inventory—II in Japan. *Psychiatry Research, 110*(3), 291–299. https://doi.org/10.1016/s0165-1781(02)00106-3

23. Lieberman, M. D., & Cunningham, W. A. (2009). Type I and Type II error concerns in fMRI research: re-balancing the scale. *Social Cognitive and Affective Neuroscience, 4*(4), 423–428. https://doi.org/10.1093/scan/nsp052

24. Marshall, S. A., Evans, S. W., Eiralld, R. B., Becker, S. P., & Power, T. J. (2014). Social and academic impairment in youth with ADHD, predominately inattentive type and sluggish cognitive tempo. *Journal of Abnormal Child Psychology, 42*(1), 77–90. https://doi.org/10.1007/s10802-013-9758-4

25. Mier, D., Lis, S., Neuthe, K., Sauer, C., Esslinger, C., Gallhofer, B., & Kirsch, P. (2010). The involvement of emotion recognition in affective theory of mind. *Psychophysiology, 47*(6), 1028–1039. https://doi.org/10.1111/j.1469-8986.2010.01031.x

26. Narama, M., Kanematsu, Y., Araki, A., Maru, M., Nakamura, N., Takeda, J., Shirahata, N., & Kudo, Y. (1999). Validity and reliability of the Japanese version of the Parenting Stress Index. *Journal of Children's Health, 58*(5), 610–616

27. Nishiyanagi, Y., Okamoto, Y., Kunisato, Y., Okada, G., Yoshimura, S., Kanai, Y., Yamamura, T., Yoshino, A., Jinnin, R., Takagaki, K., Okoda, K., & Yamawaki, S. (2015). fMRI study of social anxiety during social ostracism with and without emotional support. *PLOS ONE, 10*(5), e0127426. https://doi.org/10.1371/journal.pone.0127426

28. Nolte, T., Bolling, D. Z., Hudac, C. M., Fonagy, P., Mayes, L., & Pelphrey, K. A. (2013). Brain mechanisms underlying the impact of attachment-related stress on social cognition. *Frontiers in Human Neuroscience, 7*, 816. https://doi.org/10.3389/fnhum.2013.00816

29. Pelham, W. E., Lang, A. R., Atkeson, B., Murphy, D. A., Gnagy, E. M., Greiner, A. R., Vodde-Hamilton, M., & Greenslade, K. E. (1998). Effects of deviant child behavior on parenting style and sluggish cognitive tempo. *The American Journal on Addictions*, 7(2), 103–114

30. Posner, J., Polanczyk, G. V., & Sonuga-Barke, E. (2020). Attention-deficit hyperactivity disorder. *Lancet, 395*(10222), 450–462. https://doi.org/10.1016/S0140-6736(19)33004-1

31. Sakurai, S. (1988). The relationship between empathy and helping behavior in college students. *Bulletin of Nara University of Education (Cultural and Social Science), 37*, 149–154

32. Schmidt, A., Davies, C., Paloyelis, Y., Meyer, N., De Micheli, A., Ramella-Gravaro, V., Provenzani, U., Aoki, Y., Rutigliano, G., Cappucciati, M., Oliver, D., Murugia, S., Zelaya, F., Allen, P., Shergill, S., Morrison, P., Williams, S., Taylor, D., Borgwardt, S., Yamasue, H., McGuire, P., & Fusar-Poli, P. (2020). Acute oxytocin effects in inferring others’ beliefs and social emotions in people at clinical high risk for psychosis. *Translational Psychiatry, 10*(1), 203. https://doi.org/10.1038/s41398-020-00885-4

33. Shimabukuro, S., Daley, D., Thompson, M., Laver-Bradbury, C., Nakanishi, E., & Tripp, G. (2017). Supporting Japanese mothers of children with ADHD: Cultural adaptation of the New Forest parent training programme. *Japanese Psychological Research, 59*(1), 35–48. https://doi.org/10.1111/jpr.12140

34. Shimada, K., Kasaba, R., Fujisawa, T. X., Sakakibara, N., Takiguchi, S., & Tomoda, A. (2018). Subclinical maternal depressive symptoms modulate right inferior frontal response to inferring affective mental states of adults but not of infants. *Journal of Affective Disorders*, 229, 32–40. https://doi.org/10.1016/j.jad.2017.12.031
35. Smith, L. E., Greenberg, J. S., Seltzer, M. M., & Hong, J. (2008). Symptoms and behavior problems of adolescents and adults with autism: Effects of mother–child relationship quality, warmth, and praise. *American Journal of Mental Retardation: AJMR, 113*(5), 387–402. https://doi.org/10.1352/2008.113:387-402

36. Tully, L. A., Arseneault, L., Caspi, A., Moffitt, T. E., & Morgan, J. (2004). Does maternal warmth moderate the effects of birth weight on twins’ attention-deficit/hyperactivity disorder (ADHD) symptoms and low IQ? *Journal of Consulting and Clinical Psychology, 72*(2), 218–226. https://doi.org/10.1037/0022-006X.72.2.218

37. Woodman, A. C., Mawdsley, H. P., & Hauser-Cram, P. (2015). Parenting stress and child behavior problems within families of children with developmental disabilities: Transactional relations across 15 years. *Research in Developmental Disabilities, 36C*, 264–276. https://doi.org/10.1016/j.ridd.2014.10.011

38. Zwi, M., Jones, H., Thorgaard, C., York, A., & Dennis, J. A. (2011). Parent training interventions for attention deficit hyperactivity disorder (ADHD) in children aged 5 to 18 years. *The Cochrane Database of Systematic Reviews, 12*(12), CD003018. https://doi.org/10.1002/14651858.CD003018.pub3

**Figures**

**Figure 1**

Flow diagram of this study.

Abbreviations: Parent training (PT) group, mothers planned to be enrolled in the parent training intervention, non-PT group, mothers who were not enrolled in parent training intervention after the end of the study.

![Flow diagram](image)

**Figure 2**

Regions showing significant differences between Time 1 and Time 2 in the PT group during the RMET.

The statistical threshold was set at $p < 0.005$, uncorrected at the peak level, and $p < 0.05$, family-wise error-corrected for multiple comparisons at the cluster level. Locations were defined using the neuromorphometrics atlas implemented in SPM.

Abbreviations: PT group, mothers enrolled in the parent training intervention. PT, parent training, RMET, Reading the Mind in the Eyes Test.

**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- [MakitaSupplementaryMaterial.doc](MakitaSupplementaryMaterial.doc)
- [AuthorChecklist.pdf](AuthorChecklist.pdf)