Executive Function Training for Children with Attention Deficit Hyperactivity Disorder

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Abstract

Background: Accumulating evidence indicates that attention deficit hyperactivity disorder (ADHD) is associated with core deficits in executive function (EF) which predicts poorer academic and occupational functioning. This makes early intervention targeting EF impairments important to prevent long-term negative outcomes. Cognitive training is a potential ADHD treatment target. The present study aimed to explore the efficacy, feasibility, and acceptability of a cognitive training program (targeting child’s multiple EF components and involving parent support in daily life), as a nonpharmacological intervention for children with ADHD.

Methods: Forty-four school-age children with ADHD and their parents participated in 12 sessions of EF training (last for 12 weeks) and 88 health controls (HC) were also recruited. Training effects were explored using both neuropsychological tests (Stroop color-word test, Rey-Osterrieth complex figure test, trail making test, tower of Hanoi, and false-belief task) and reports of daily life (ADHD rating scale-IV, Conners’ parent rating scale, and behavior rating inventory of executive function [BRIEF]) by analysis of paired sample t-test and Wilcoxon signed-rank test. The differences on EF performances between children with ADHD after training and HC were explored using multivariate analysis.

Results: The results (before vs. after EF training) showed that after intervention, the children with ADHD presented better performances of EF both in neuropsychological tests (word interference of Stroop: 36.1 ± 14.6 vs. 27.1 ± 11.1, t = 4.731, P < 0.001; shift time of TMT: 194.9 ± 115.4 vs. 124.8 ± 72.4, Z = −4.639, P < 0.001; false-belief task: χ² = 6.932, P = 0.008) and reports of daily life (global executive composite of BRIEF: 148.9 ± 17.5 vs. 127.8 ± 17.5, t = 6.433, P < 0.001). The performances on EF tasks for children with ADHD after EF training could match with the level of HC children. The ADHD symptoms (ADHD rating scale total score: 32.4 ± 8.9 vs. 22.9 ± 8.2, t = 6.331, P < 0.001) and behavioral problems of the children as reported by parents also reduced significantly after the intervention. Participants reported that the EF training program was feasible to administer and acceptable.

Conclusions: The EF training program was feasible and acceptable to children with ADHD and parents. Although replication with a larger sample and an active control group are needed, EF training program with multiple EF focus and parent involving in real-life activities could be a potentially promising intervention associated with significant EF (near transfer) and ADHD symptoms improvement (far transfer).

Key words: Attention Deficit Hyperactivity Disorder; Cognitive Behavior Therapy; Executive Function

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is one of the most common mental and behavior disorders in childhood with recent estimates from studies indicating that at least 3.0–7.8% of the general population meet the criteria for the disorder.1-3 Accumulating evidence indicates that ADHD is associated with core deficits in executive function (EF).4-6

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The concept of EF is generally agreed to be a product of the coordinated operation of various processes undertaken to accomplish a particular goal in a flexible manner, including components such as inhibition, working memory (WM), planning, flexibility, and verbal fluency (VF) as cold EF, and theory of mind (ToM) as hot EF.[5-7]

Studies indicate that childhood EF predicts academic and occupational functioning. A cohort study following 1000 children from birth to the age of 32 years demonstrated that childhood EF predicted physical health, substance dependence, personal finances, and criminality independent of intelligence and social class.[8] Therefore, it is important to target EF impairments early in life to prevent long-term difficulties.[9,10]

Front-line ADHD treatment is normally medication which can help reduce the symptoms and improve EF. However, lack of compliance, reservations about medication use from some parents, and failure to target academic and social functions mean medication alone may be insufficient.[11-14] Functional improvement requires both improvement in core symptoms and the opportunity to develop and apply new skills and reduce impairment.[15] Cognitive training is a potential ADHD treatment which was reported to have significant effects on ADHD symptoms with raters most proximal to treatment delivery, although these effects reduced substantially when assessors were probably blind to treatment allocation.[16,17] However, all the studies in previous review did not provide additional support to parents to coach their child’s acquisition of EF skills in real-life activities.[17] Only recently had researchers started to explore the impact of parenting variables on the development of EF in children and understand the positive role that parental interaction and support can play on the typical development of EF.[18,19]

The purpose of this study was to explore whether combining traditional EF training for children with ADHD with behavioral intervention for parents could improve the EF and ADHD symptoms in children with ADHD.

Methods

Participants

The study included 44 Chinese children diagnosed with ADHD (ADHD group) through the Clinical Diagnostic Interviewing Scales.[20,21] Participants in ADHD group were recruited from the outpatient clinics at Xinhua Hospital and the Peking University Sixth Hospital in China from February 2006 to December 2012, including 23 combined type, 18 inattentive type, and three hyperactive-impulsive type. Twenty-three children presented with comorbidities (15 oppositional defiant disorder; one conductive disorder; four tics; one special phobia; and two anxiety). ADHD with severe comorbidities such as major depression, mania, and bipolar disorder were excluded. Five participants were taking medications (three children on methylphenidate and two children on atomoxetine) who were asked to maintain a stable medication status during the intervention and evaluation period.

The 88 children as health control (HC) were recruited from two primary schools. They were matched with the ADHD group by age (within 6 months) and intelligence quotient (IQ) (within 15-scaled score points). The matching process aimed to decrease error variance and prevent matching variables from becoming competing causal factors for any effect.[22] The children in HC group were administered the same interview and EF tasks battery as ADHD group, with purpose to investigate whether the ADHD group could reach the normal EF level after treatment.

Children with major sensory-motor difficulties (e.g., paralysis, deafness, and blindness), a history of brain damage, epilepsy, or an estimated full-scale IQ of <80 (using Wechsler Intelligence Scale for Chinese Children-Revised) were excluded for both groups.

The study was approved by the Ethics Committee of the Xinhua Hospital, and informed consent and assent were obtained from all parents and children.

Measurements

Rating scales

ADHD rating scale-IV: Parent rated ADHD symptom including intention, hyperactivity, and impulsivity about their children.[23]

Conners’ parent rating scale: Six factor were measured: conduct, learning, psychosomatic, impulsive-hyperactive, anxiety problems, and a hyperactivity index.[24]

Behavior rating inventory of executive function (BRIEF): The instrument included eight factors measuring parental reports of EF: initiate, WM, plan/organize, organization of materials, monitor (formed metacognition index [MI]), inhibit, shift, and emotional control (formed behavioral regulation index [BRI]).[25]

Parent report and satisfaction survey: This questionnaire was designed to gather information from the parent about child’s behaviors at home and academic performance at school, as well as the parent’s opinions about the intervention.

Neuropsychological measures

In this study, the neuropsychological assessments were selected to cover the comprehensive domains of EF components. The Chinese versions of these tests have been found to discriminate well between ADHD and age-/IQ-matched HC.[26]

The Stroop color and word test was used to capture the inhibition component of EF.[27] The test consisted of four parts as word naming (Part 1), color naming (Part 2), color interference (Part 3), and word interference (Part 4). The time taken to complete Part 3 was subtracted from that for Part 1 to indicate color interference, and the time taken to complete Part 4 was subtracted from that for Part 2 to indicate word interference.

The Rey-Osterrieth complex figure test (RCFT) was used to evaluate visuospatial construction ability and visual WM.[28] This test estimates participants’ short- and long-term memory
The aim of the training program was to help the child develop the skills and strategies needed to cope with the difficulties and impairments associated with ADHD. The intervention had the following features:

1. Targeting multiple EF components related to ADHD including inhibition, WM, planning and organization, shifting, ToM, time management, and emotional regulation because EF training transfer is narrow, the training protocol targeted a broad range of neuropsychological deficits.

2. Intervene both with the child and the child’s environment. In addition to targeting intervention at the child by teaching them executive skills, motivating them to practice and use the skills, the training program also intervened via the child’s environment by changing the task nature and ways support and cues were provided. Combining these two strategies, the executive skills ADHD children lacked were taught externally, promoted to practice, and used to the point where the child could apply the skill independently, in a way that became habitual and automatic.

3. Involving Parent. The parents were provided with psychoeducation about ADHD, information about behavioral management skills (behavioral contract, response cost, etc.), and other skills necessary for living with and raising children with ADHD (eye contact, giving short direction, capturing good moment, etc.). Parental intervention can improve both the child’s behavior and parental function.

4. Implementing in daily life by assigning homework to make sure the child exercised and used the EF skills, as well as to coach the parent on how to support and promote the child’s EF in real-life activities.

### Statistical analysis

Statistical analysis was performed using SPSS version 19.0 (IBM, SPSS Software, Armonk, New York, USA). Differences were deemed significant when \( P < 0.05 \), in line with advice from Perneger control for multiple measures was not applied.

First, differences in EF tests were explored between baseline and training completion, as well as the child’s everyday life EF and behaviors reported by the parent. Parametric variables were analyzed using \( t \)-tests. Nonparametric variables were analyzed using nonparametric Wilcoxon signed-rank tests. All statistical tests were two-tailed. Second, we explored differences on EF performances between children with ADHD after training and HC using multivariate analysis of covariance controlling for age and IQ.

### Results

Outcomes included parent ratings of ADHD symptoms, other behavioral problems, and EF performance both in the laboratory and in real life.

Table 1 lists the results (before vs. after EF training) for parental ratings. Parents rated their children as having fewer ADHD symptoms on the ADHD rating scale-IV inattentive, hyperactive-impulsive, and total score (32.4 ± 8.9 vs. 28.7 ± 7.9).
Table 1: Mean score of each scale before and after executive function training for parental ratings (n = 40)

| Subscale                                      | ADHD-before training | ADHD-after training | Statistical value | \( P \)  |
|-----------------------------------------------|----------------------|--------------------|-------------------|-------|
| **ADHD Rating Scale-IV (symptom item)**       |                      |                    |                   |       |
| Inattentive                                   | 7.4 ± 1.6            | 4.5 ± 2.3          | 7.182*            | <0.001|
| Hyperactive-impulsive                         | 4.7 ± 2.6            | 2.6 ± 2.3          | 5.442*            | <0.001|
| Total item                                    | 12.1 ± 3.7           | 7.1 ± 4.1          | 6.960*            | <0.001|
| **ADHD rating scale-IV (symptom score)**     |                      |                    |                   |       |
| Inattentive                                   | 18.6 ± 3.8           | 13.7 ± 3.9         | 6.381*            | <0.001|
| Hyperactive-impulsive                         | 13.5 ± 6.2           | 9.2 ± 5.5          | 4.990*            | <0.001|
| Total score                                   | 32.4 ± 8.9           | 22.9 ± 8.2         | 6.331*            | <0.001|
| **Conners’ parent rating scale**              |                      |                    |                   |       |
| Conduct problem                               | 8.7 ± 5.0            | 5.7 ± 4.2          | 5.394*            | <0.001|
| Learning problem                              | 7.4 ± 1.9            | 5.7 ± 2.1          | 4.603*            | <0.001|
| Psychosomatic                                 | 1.4 ± 1.7            | 0.8 ± 1.1          | −2.027†           | 0.043 |
| Impulsive-hyperactive                         | 5.7 ± 3.2            | 3.6 ± 2.4          | 5.102*            | <0.001|
| Anxiety                                       | 2.5 ± 1.9            | 1.4 ± 1.5          | −4.112†           | <0.001|
| Hyperactivity index                           | 14.1 ± 5.2           | 9.4 ± 4.8          | 6.860*            | <0.001|
| **BRIEF**                                     |                      |                    |                   |       |
| Inhibition                                    | 19.1 ± 4.8           | 15.8 ± 4.1         | 4.669*            | <0.001|
| Shift                                         | 12.6 ± 2.8           | 11.7 ± 2.3         | 1.992*            | 0.054 |
| Emotional control                             | 17.2 ± 5.0           | 14.6 ± 3.5         | 3.815*            | 0.001 |
| Initiate                                      | 15.1 ± 2.8           | 12.8 ± 2.2         | 4.920*            | <0.001|
| Working memory                                | 22.7 ± 2.9           | 20.0 ± 2.8         | 4.262*            | <0.001|
| Plan                                          | 28.0 ± 3.2           | 24.1 ± 4.0         | 5.409*            | <0.001|
| Organize                                      | 13.8 ± 2.8           | 11.6 ± 2.7         | 4.611*            | <0.001|
| Monitor                                       | 20.3 ± 2.5           | 17.4 ± 3.4         | 6.097*            | <0.001|
| Behavior regulation index                     | 48.4 ± 9.6           | 42.0 ± 7.7         | 4.153*            | <0.001|
| Metacognition index                           | 100.0 ± 10.1         | 85.8 ± 11.6        | 6.365*            | <0.001|
| Global executive composite                    | 148.9 ± 17.5         | 127.8 ± 17.5       | 6.433*            | <0.001|

Data were presented with mean ± SD. *t value; †Z value; ‡Two BRIEF scales were eliminated because the validity issue including negativity and inconsistency. SD: Standard deviation; ADHD: Attention deficit hyperactivity disorder; BRIEF: Behavior rating inventory of executive function.

22.9 ± 8.2, \( t = 6.331, P < 0.001 \) after treatment. Significant improvements were found for the Conner’s parent rating scale on all factors and BRIEF except shift (MI: 100.0 ± 10.1 vs. 85.8 ± 11.6, \( t = 6.365, P < 0.001 \); BRI: 48.4 ± 9.6 vs. 42.0 ± 7.7, \( t = 4.153, P < 0.001 \); Global executive composite: 148.9 ± 17.5 vs. 127.8 ± 17.5, \( t = 6.433, P < 0.001 \)).

Changes in children’s performance in EF tests are presented in Table 2. For the Stroop test, the time used for all the parts was significantly shorter after treatment. Errors in the word inhibition subtest (2.2 ± 2.3 vs. 1.3 ± 1.3, \( Z = -2.079, P = 0.038 \)) and word interference (36.1 ± 14.6 s vs. 27.1 ± 11.1 s, \( t = 4.731, P < 0.001 \)) reduced significantly. In RCFT, both the scores on structure (immediate: 1.9 ± 2.0 vs. 3.3 ± 2.1, \( Z = -4.512, P < 0.001 \); delay: 1.8 ± 2.0 vs. 3.2 ± 2.1, \( Z = -3.498, P < 0.001 \)) and detail (immediate: 6.5 ± 5.8 s vs. 12.1 ± 7.4, \( t = -7.590, P < 0.001 \); delay: 6.4 ± 5.7 vs. 11.7 ± 7.1, \( t = -6.340, P < 0.001 \)) were significantly increased. In contrast, the forgotten scores did not present significant change. In TMT, the time spent in all the parts (shift time: 194.9 ± 115.4 s vs. 124.8 ± 72.4 s, \( Z = -4.639, P < 0.001 \)), and the errors made in Part 2 (1.8 ± 2.1 vs. 0.7 ± 1.1, \( Z = -3.264, P = 0.002 \)) were significantly reduced. In ToH, the participants needed less time and fewer steps to finish the task, making fewer violations during the task (2.2 ± 2.5 vs. 0.5 ± 0.8, \( Z = -4.780, P < 0.001 \)).
The intervention sample postintervention was compared with HC on aspects of the EF. Table 4 indicates that there were no significant differences between these two groups on age (8.4 ± 0.9 years vs. 8.4 ± 0.8 years, \( t = -0.126, P = 0.900 \)) and IQ (106.3 ± 12.1 vs. 106.4 ± 11.6, \( t = -0.063, P = 0.950 \)). The performances are listed in Table 5. There were no significant differences on Stroop (word interference: 27.1 ± 11.1 s vs. 28.1 ± 11.9 s, \( F = 0.814, P = 0.369, \eta^2P = 0.006 \)), TMT (shift time: 124.8 ± 72.4 s vs. 118.6 ± 73.5 s, \( F = 0.023, P = 0.879, \eta^2P < 0.001 \)) and false-belief task (\( \chi^2 = 0.007, P = 0.932 \)). While the children with ADHD after training performed better in RCFT, ToH, and VF, compared with NC. However, most of the ES of these differences was very small (between 0 and 0.047), except for the detail scores in RCFT and accomplish time in ToH (between 0.090 and 0.157).

**Discussion**

**Efficacy**

The goal of this study was to evaluate a nonpharmacological intervention for children with ADHD in routine clinical practice to address difficulties associated with EF impairment, given the link between EF impairment and educational and social difficulties.\(^{[41]}\)

Children’s performance improved significantly on all of the EF tests. The participants demonstrated improvement not only in basic processing speed (Part 1 and 2 of Stroop, Part 1 of TMT) but also on the higher level of the cognitive function such as interference inhibition (Part 3 and 4 of Stroop),\(^{[42,43]}\) and efficient shifting (Part 2 of TMT).\(^{[40]}\) The improvements in RCFT indicated that the WM skills on both grasping

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**Table 2: Children’s performance of each EF tests before and after EF training (n = 44)**

| EF tests             | ADHD-before training | ADHD-after training | Statistical value | \( P \)  |
|----------------------|----------------------|---------------------|-------------------|---------|
| Stroop               |                       |                     |                   |         |
| Part 1 time (s)      | 23.4 ± 5.4            | 21.5 ± 6.5          | 2.199*            | 0.033   |
| Part 2 time (s)      | 30.7 ± 9.1            | 27.5 ± 6.4          | 3.506*            | 0.001   |
| Part 3 time (s)      | 31.8 ± 12.7           | 27.1 ± 9.0          | 3.515*            | 0.001   |
| Part 4 time (s)      | 66.8 ± 18.1           | 54.6 ± 15.4         | 6.481*            | <0.001  |
| Part 1 error         | 0.3 ± 0.6             | 0.1 ± 0.3           | −1.941\( ^* \)    | 0.052   |
| Part 2 error         | 0.3 ± 0.7             | 0.2 ± 0.4           | −0.966\( ^* \)    | 0.334   |
| Part 3 error         | 0.7 ± 1.4             | 0.4 ± 0.7           | −1.214\( ^* \)    | 0.225   |
| Part 4 error         | 2.2 ± 2.3             | 1.3 ± 1.3           | −2.079\( ^* \)    | 0.038   |
| Color interference (s)| 8.4 ± 9.4             | 5.6 ± 5.6           | −1.835\( ^* \)    | 0.066   |
| Word interference (s)| 36.1 ± 14.6           | 27.1 ± 11.1         | 4.731*            | <0.001  |
| RCFT                 |                       |                     |                   |         |
| Structure immediate  | 1.9 ± 2.0             | 3.3 ± 2.1           | −4.512\( ^* \)    | <0.001  |
| Structure delay      | 1.9 ± 2.0             | 3.2 ± 2.1           | −3.498\( ^* \)    | <0.001  |
| Structure forgotten  | 0 ± 0.9               | 0.7 ± 0.7           | −0.394\( ^* \)    | 0.693   |
| Detail immediate     | 6.5 ± 5.8             | 12.1 ± 7.4          | −7.590\( ^* \)    | <0.001  |
| Detail delay         | 6.4 ± 5.7             | 11.7 ± 7.1          | −6.340\( ^* \)    | <0.001  |
| Detail forgotten     | 0.1 ± 2.5             | 0.4 ± 1.8           | −0.182\( ^* \)    | 0.856   |
| Trail making test    |                       |                     |                   |         |
| Part 1 time (s)      | 77.4 ± 30.8           | 62.4 ± 24.1         | 4.457*            | <0.001  |
| Part 2 time (s)      | 272.3 ± 123.3         | 187.2 ± 81.1        | 5.551*            | <0.001  |
| Shift time (s)       | 194.9 ± 115.4         | 124.8 ± 72.4        | −4.639\( ^* \)    | <0.001  |
| Part 1 error         | 0.2 ± 0.5             | 0.1 ± 0.3           | −1.000\( ^* \)    | 0.317   |
| Part 2 error         | 1.8 ± 2.1             | 0.7 ± 1.1           | −3.264\( ^* \)    | 0.001   |
| Tower of Hanoi       |                       |                     |                   |         |
| Complete/fail        | 32/12                 | 39/5                | 2.625\( ^* \)     | 0.105   |
| Initiation time (s)  | 0.5 ± 1.2             | 0.5 ± 3.0           | −1.614\( ^* \)    | 0.107   |
| Accomplish time (s)  | 254.8 ± 173.9         | 131.5 ± 86.1        | 4.063*            | <0.001  |
| Accomplish steps     | 42.5 ± 28.2           | 32.3 ± 16.7         | 2.296*            | 0.029   |
| Error steps          | 2.2 ± 2.5             | 0.5 ± 0.8           | −4.780\( ^* \)    | <0.001  |
| Verbal fluency test  |                       |                     |                   |         |
| Correct first 1 min  | 12.6 ± 4.0            | 13.9 ± 4.0          | −2.652*            | 0.011   |
| Correct last 1 min   | 5.2 ± 2.7             | 5.8 ± 2.9           | −1.572*            | 0.123   |
| Total correct        | 17.8 ± 4.9            | 19.8 ± 5.2          | −3.325*            | 0.002   |
| Repeat responses     | 0.7 ± 0.9             | 0.6 ± 1.0           | −1.086\( ^* \)    | 0.278   |
| Error responses      | 0.1 ± 0.3             | 0.1 ± 0.3           | 0\( ^* \)          | 1.000   |
| False-belief task (C/W)| 26/18                 | 38/6                | 6.932\( ^* \)     | 0.008   |

Data were presented with mean ± SD and \( n \). \( t \) value; \( Z \) value; \( \chi^2 \) value; \( \eta^2 \) value; \( \chi^2 \) value; \( \eta^2 \) value; 32 children who completed tower of Hanoi successfully both before and after training. ADHD: Attention deficit hyperactivity disorder; EF: Executive function; SD: Standard deviation; RCFT: Rey-Osterrieth complex figure test; C/W: Correct answer/wrong answer.

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Table 3: Results of the consumer investigation and satisfaction rating scale for the training program (n = 40)

| Questions                                                                 | Before training | After training | Statistical value | P    |
|---------------------------------------------------------------------------|-----------------|----------------|--------------------|------|
| Children’s behavior at home ([none + sometimes]/[usually + always]), n   | 19/21           | 33/7           | 9.286*             | 0.002|
| Impulsivity                                                               | 14/26           | 37/3           | 26.180*            | <0.001|
| Difficult waiting                                                         | 38/2            | 16/24          | 25.128*            | <0.001|
| Efficient homework completion                                             | 1/39            | 16/24          | 14.641*            | <0.001|
| Distraction during homework                                               | 9/31            | 27/13          | 14.596*            | <0.001|
| Poor organization                                                         | 26/14           | 8/32           | 14.783*            | <0.001|
| Following parental requests                                               |                 |                |                    |      |
| Parents’ perspective ([none + sometimes]/[usually + always]), n           | 10/30           | 33/7           | 24.337*            | <0.001|
| Disappointed at child’s behaviors                                          | 8/32            | 23/17          | 10.323*            | 0.001|
| Disappointed at child’s studies                                            | 31/9            | 13/27          | 14.596*            | <0.001|
| Communicated with the child in a good way                                  | 37/3            | 8/32           | 39.822*            | <0.001|
| Reward the child with a system                                            | 35/5            | 12/28          | 24.965*            | <0.001|
| Punish the child with a system                                            | 37/3            | 17/23          | 20.570*            | <0.001|
| Can motivate the child                                                     |                 |                |                    |      |
| Children’s study performance, mean ± SD                                    | 77.5 ± 14.0     | 80.0 ± 12.3    | −2.584†            | 0.014|
| Mean score during the latest examination                                   | 29.2 ± 20.2     | 37.2 ± 22.6    | −3.553†            | 0.001|
| Rank ([child’s place/total number of the class)]                          |                 |                |                    |      |

*χ² value; †t value. ADHD: Attention deficit hyperactivity disorder; SD: Standard deviation.

Table 4: Mean score of demographic variables for children with ADHD and health controls

| Demographic variables | Children with ADHD (n = 44) | Health controls (n = 88) | t     | P      |
|-----------------------|-----------------------------|--------------------------|-------|--------|
| Age (years)           | 8.4 ± 0.9                   | 8.4 ± 0.8                | −0.126| 0.900  |
| VIQ                   | 110.1 ± 14.2                | 107.8 ± 14.9             | 0.726 | 0.470  |
| PIQ                   | 100.3 ± 12.0                | 103.3 ± 10.9             | −1.198| 0.234  |
| IQ                    | 106.3 ± 12.1                | 106.4 ± 11.6             | −0.063| 0.950  |

Data were presented as mean ± SD. VIQ: Verbal intelligence quotient; PIQ: Performance intelligence quotient; IQ: Total intelligence quotient; SD: Standard deviation; ADHD: Attention deficit hyperactivity disorder.

program was aimed at multiple EF components to obtain overall improvement.

In addition to improvements on cold EF, the children also showed progress on hot EF, which was important because poor ToM might also represent a prognostic marker or predictor of worse functional outcome and greater clinical need. The treatment for children with ADHD, both medication and nonmedication methods, rarely reports an impact on ToM. In fact, emotional regulation and social understanding skills aiming for improving ToM element might address children’s stress in their lives, giving children a sense of belonging and social acceptance, which would probably improve EF and school outcomes.

The performances on EF tasks for children with ADHD after EF training were matched with the level of HC children. However, medication including both methylphenidate and atomoxetine could improve the performances on some EF subtests but still could not achieve the normal level in Stroop test and TMT. Therefore, EF training program is an important and useful candidate for children with ADHD to reduce the EF developmental gap by teaching children appropriate coping skills and strategies.

The EF improvements not only showed in the laboratory tests but also showed in the child’s everyday life captured by BRIEF. These indicated that a wide variety of EF skills were improved in child’s real daily life, which were very important since the everyday EF problems were predictors of comorbid psychopathology.

In addition to EF improvements on neuropsychological tests and daily life, the child’s ADHD symptoms and behaviors also showed significant improvements. This was in line with a study using meta-cognitive therapy, which targeted EF impairments and developed self-management skills.
skills showed marked improvement with respect to adult’s ADHD symptoms. However, some previous studies, focusing on training WM or inhibition, could not lead to the generalized improvement of ADHD symptoms or behaviors. Therefore, the cognitive training program should be tailored to meet child’s real-world situations or settings. In this study, the intervention was intertwined with relevant real-life EF activities (e.g., completing chores in daily life), which might be the reason for the more ecologically valid effect. The parent involvement might also contribute to these improvements because parenting interventions were beneficial for ADHD symptom reduction and neuropsychological function. Some other interventional studies required parent to learn, and administer activities targeting child’s EF also showed an impact on ADHD symptoms and other disruptive behaviors. Actually, the intervention with the parent implemented in the home setting dramatically intensifies the dose of intervention, and moreover, the intervention is integrated into the daily activities.

Good academic performance is an important issue for Chinese parents not only because it is thought to be an important stepping stone to success, but also because it reflects well on parents and family in Chinese culture. Therefore, it was very meaningful and important to help the children with ADHD improve their school outcomes. After treatment, children got better scores in later examinations, and also increased their rank in the class.

| EF tests                        | ADHD-after training (n = 44) | Health controls (n = 88) | F or χ² | P    | η²P |
|---------------------------------|-----------------------------|--------------------------|---------|------|-----|
| Stroop                          |                             |                          |         |      |     |
| Part 1 time (s)                 | 21.5 ± 6.5                  | 21.1 ± 6.0               | 0       | 0.996| 0.000|
| Part 2 time (s)                 | 27.5 ± 6.4                  | 26.4 ± 5.9               | 0.420   | 0.518| 0.003|
| Part 3 time (s)                 | 27.1 ± 9.0                  | 26.9 ± 8.3               | 0.043   | 0.837| 0.000|
| Part 4 time (s)                 | 54. ± 615.4                | 54.5 ± 15.0              | 0.215   | 0.643| 0.002|
| Part 1 error                    | 0.1 ± 0.3                   | 0.1 ± 0.4                | 0.478   | 0.490| 0.004|
| Part 2 error                    | 0.2 ± 0.4                   | 0.2 ± 0.4                | 0.004   | 0.948| 0.000|
| Part 3 error                    | 0.4 ± 0.7                   | 0.3 ± 0.6                | 0.664   | 0.417| 0.005|
| Part 4 error                    | 1.3 ± 1.3                   | 0.9 ± 1.3                | 2.464   | 0.119| 0.019|
| Color interference (s)          | 5.6 ± 5.6                   | 5.9 ± 6.2                | 0.080   | 0.778| 0.001|
| Word interference (s)           | 27.1 ± 11.1                 | 28.1 ± 11.9              | 0.814   | 0.369| 0.006|
| RCFT                            |                             |                          |         |      |     |
| Structure immediate             | 3.3 ± 2.1                   | 2.6 ± 2.0                | 6.261   | 0.014| 0.047|
| Structure delay                 | 3.2 ± 2.1                   | 2.7 ± 1.9                | 3.981   | 0.048| 0.030|
| Structure forgotten             | 0.7 ± 0.7                   | −1.2 ± 0.9               | 1.836   | 0.178| 0.014|
| Detail immediate                | 12.1 ± 7.4                  | 8.9 ± 5.5                | 13.724  | <0.001| 0.097|
| Detail delay                    | 11.7 ± 7.1                  | 8.7 ± 5.4                | 12.715  | 0.001| 0.090|
| Detail forgotten                | 0.4 ± 1.8                   | 0.2 ± 1.9                | 0.368   | 0.545| 0.003|
| Trail making test               |                             |                          |         |      |     |
| Part 1 time (s)                 | 62.4 ± 24.1                 | 63.9 ± 23.2              | 0.451   | 0.503| 0.004|
| Part 2 time (s)                 | 187.2 ± 81.1                | 182.5 ± 82.4             | 0.003   | 0.954| 0.000|
| Shift time (s)                  | 124.8 ± 72.4                | 118.6 ± 73.5             | 0.023   | 0.879| 0.000|
| Part 1 error                    | 0.1 ± 0.3                   | 0.1 ± 0.4                | 0.001   | 0.977| 0.000|
| Part 2 error                    | 0.7 ± 1.1                   | 0.8 ± 1.0                | 0.530   | 0.468| 0.004|
| Tower of Hanoi                  |                             |                          |         |      |     |
| Complete/fail                   | 39/5                        | 61/27                    | 4.955   | 0.026|       |
| Initiation time (s)             | 0.5 ± 3.0                   | 4.0 ± 20.5               | 1.357   | 0.246| 0.010|
| Accomplish time (s)             | 143.2 ± 98.9                | 252.7 ± 168.7            | 17.843  | <0.001| 0.157|
| Accomplish steps                | 33.1 ± 16.4                 | 32.1 ± 15.7              | 0.030   | 0.862| 0.000|
| Error steps                     | 0.5 ± 0.8                   | 0.9 ± 1.2                | 4.686   | 0.032| 0.035|
| Verbal fluency test             |                             |                          |         |      |     |
| Correct first 1 min             | 13.9 ± 4.0                  | 13.1 ± 3.6               | 3.700   | 0.055| 0.028|
| Correct last 1 min              | 5.8 ± 2.9                   | 5.4 ± 2.7                | 1.800   | 0.186| 0.014|
| Total correct                   | 19.8 ± 5.2                  | 18.4 ± 4.9               | 5.100   | 0.026| 0.038|
| Repeat responses*               | 0.6 ± 1.0                   | 0.5 ± 0.7                | 0.200   | 0.675| 0.001|
| Error responses*                | 0.1 ± 0.3                   | 0 ± 0.2                  | 0.500   | 0.536| 0.003|
| False-belief task (C/W)          | 38/6                        | 74/14                    | 0.007   | 0.932|       |

*χ² value. Data were presented as mean ± SD or as n. ADHD: Attention deficit hyperactivity disorder; EF: Executive function; SD: Standard deviation; RCFT: Rey-Osterrieth complex figure test; C/W: Correct answer/wrong answer.
calculation and reading. Therefore, the benefits of EF training program especially targeting on inhibition, WM, and planning could be extended to child’s learning skills and various aspects of schooling.[35,71,72]

Feasibility
The results from this study suggested that the EF training program was feasible to administer and could be successfully administered. Attendance was acceptable; every participant attends at least 10 sessions (>80% attendance rate). The dropout rate was 8%, which was particularly impressive given the fact that families were asked to attend this program weekly for 12 weeks. Most dropouts occurred during the first two classes, which means both parent and the child need at least one session to determine whether the treatment suited their needs.

Acceptability
Consumer investigation and satisfaction rating scale revealed that 72.5% parents could usually or always understand the strategies and implement them in their daily life. About 95% of parents were usually or always satisfied with the EF training program and would like to recommend this treatment to other parents who had children with ADHD. After attending the EF training program, the parents felt less disappointed and helpless about the child’s behaviors and school work, they knew how to better communicate with their child, how to reward and punish the child in an appropriate way, how to motivate their child.

Limitations
A few limitations of this study should be noted. Although data were collected for 44 children with ADHD and 88 HC, the sample size was still small. The absence of a waiting group does not allow us to rule out the natural change as a result of the development of children.

This was an open trial, although the person who evaluated the EF was blind to the participant’s situation, parental reports may still have been subjective. A recent meta-analysis has demonstrated that the significant treatment effects for ADHD identified using the most proximal respondents were usually lost when probably blinded assessments and informants were used, and it has not been possible to explore this issue in this data set.[35]

Therefore, a randomized controlled trial with a larger sample of children with ADHD, which includes a waiting list group that does not receive intervention, data from teachers who are not aware of the child’s treatment state will be a necessary next step to explore the efficacy of this EF training program.

Overall, the results of this open trial suggested that EF training program was a feasible intervention to administer in a population of school-aged children with ADHD. Preliminary analyses suggested that the intervention was effective in improving cool EF including inhibition, WM, shifting, planning, VF and hot EF, as well as reducing ADHD symptoms, and improving aspects of daily life.

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Conflicts of interest
There are no conflicts of interest.

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