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PRE PRINT VERSION

Examining the Effectiveness of Group Games in Enhancing Inhibitory Control in Preschoolers

Abstract

Research Findings: Promoting inhibitory control in preschoolers could increase the likelihood of positive developmental trajectories. Nevertheless, to date only a limited number of studies have focused on inhibitory control training, reporting mixed results. To examine the efficacy and the transfer effects of the training on preschoolers, seven group games based on body movement were developed and administered across 15 sessions of 30 minutes each at preschool three times a week for over five weeks. Fifty-one children aged four to five years were randomly assigned to either a control group consisting of 14 girls and 13 boys (M_{age}=4.58; S.D.=0.32) or a training group with 13 girls and 11 boys (M_{age}=4.60; S.D.=0.30). The training group had four subgroups consisting of six children each. The pretests and delayed posttests examined executive functions and pre-academic skills while immediate posttests examined only executive functions. There was three months interval between immediate and delayed posttests. Improvements in inhibitory control, other executive functions, and mathematical cognition in the experimental group were greater than those in the control group. *Practice or Policy*: This design of group games for inhibitory control in preschoolers is effective and it can be improved by expanding game categories and enhancing training environment.

Keywords: preschoolers, inhibitory control, training, group games, executive functions

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Introduction

Executive functions (EFs) refer to top-down control processes that allow the regulation of thoughts and behavior when automatic or instinct response is inappropriate, which include three core subcomponents which are inhibitory control, working memory, and cognitive flexibility (Diamond, 2013). These cognitive skills are essential for mental and physical health, success in school and daily life, as well as cognitive and social-emotional development (Blair & Razza, 2007; Moffitt et al., 2011). Inhibitory control, as the domain-general skill of EFs, develops rapidly in the preschool period (Best & Miller, 2010) and it has been found to affect different aspects of child functioning, e.g., self-regulation (Rueda, Posner, & Rothbart, 2005), social emotional competence (Rhoades, Greenberg, & Domitrovich, 2009), and academic skills (Allan, Hume, Allan, Farrington, & Lonigan, 2014). Recently, some studies showed that providing a rich learning environment in a period of rapid development of inhibitory control is helpful to raise the development level of inhibitory control and result in long-term impacts such as improvement in early academic skills (Schmitt, McClelland, Tominey, & Acock, 2015; Tominey & McClelland, 2011) and behavioral regulation (Volckaert & Noël, 2015). However, only a few of studies have investigated the efficacy of the inhibitory control training and mixed results were reported (Liu, Zhu, Ziegler, & Shi, 2015; Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009; Volckaert & Noël, 2015). This study was designed to develop the inhibitory control training and examine its efficacy and transfer effects in preschoolers.

Inhibitory Control and Early Child Development

Inhibitory control involves being able to control one's attention, behavior, thoughts, and/or emotions to override a strong internal predisposition or external lure, and do what is more appropriate or needed (Diamond, 2013). Inhibitory control shows rapid improvements in early childhood and it slows down in later childhood and adolescence (Best & Miller, 2010). In particular, the preschool period is crucial for the development of this ability (Garon, Bryson, & Smith, 2008). Although the differentiation in EFs gradually emerges during childhood, inhibitory control, though related to the other executive dimensions, has been a separate dimension in the preschool years (Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012; Monette, Bigras, & Lafrenière, 2015; Usai, Viterbori, Traverso, & De Franchis, 2014).

Inhibitory control in preschoolers can predict diverse developmental outcomes such as flexibility (Diamond, Carlson, & Beck, 2005), problem-solving (Senn, Espy, & Kaufmann, 2004), theory of mind (Carlson, Moses, & Claxton, 2004), social emotional competence (Rhoades et al., 2009), early academic skills (Allan et al., 2014; Harvey & Miller, 2016; Son, Choi, & Kwon, 2019), and later mathematical and reading achievement (Hernández et al., 2018). Specially, there are both direct and indirect effects of inhibitory control on early academic skills. First, inhibitory control enables preschoolers to effectively manage cognitive and behavioral demands of schooling (e.g., concentrate on relevant stimuli in the presence of irrelevant stimuli) and focus on classroom learning activities (Allan et al., 2014; McClelland et al., 2007; Son et al., 2019). Second, inhibitory control can influence early academic skills through other factors; for example, as suggested by Allan et al. (2014), inhibitory control, by virtue of regulating children's emotional responses, facilitates positive teacher-child interactions which in turn influence early academic skills (see also Valiente et al., 2011).

Inhibitory Control Training and Program Evaluation Studies

Studies showed that environmental factors, such as socioeconomic status, parenting, and parent-child interactions, can affect the development of preschoolers' EFs (Cuevas et al., 2014; Fay-Stammbach, Hawes, & Meredith, 2014; Raver, Blair, & Willoughby, 2013; Rhoades, Greenberg, Lanza, & Blair, 2011). Therefore, it is necessary to investigate the possibility to enhance inhibitory control through specific stimuli during inhibitory control training.

In recent years, various types of EFs training have emerged, but their effects on inhibitory control have been limited (Diamond & Lee, 2011). Only a few of them have focused on inhibitory control training and these studies reported mixed results. Although some studies reported that the inhibitory control training was effective and allowed to obtain improvement in behavioral regulation (Volckaert & Noël, 2015) and in early school achievement (Schmitt et al., 2015; Tominey & McClelland, 2011), other studies reported no training benefits. It could be because different forms of training have different effects on the acquisition process of inhibitory control skills. For example, in the study by Thorell et al. (2009), the computerized training of inhibition for five weeks could only improve the performance of children between the ages of four to five in two out of three trained task paradigms, but not in the non-trained inhibitory tasks. Goldin et al. (2014) developed three adaptive computer games for training working memory, planning, and inhibitory control skills of six-year-olds but did not find any training effect on inhibitory control. Liu et al. (2015) evaluated the transfer effects of the “Fruit Ninja” game every day for 15 minutes, four days a week, for three weeks on five-year-olds, and did not find any training effect on the behavioral performance of inhibitory control tasks. Although computerized games have advantages in presenting self-adaptive difficulty and timely feedback, their training effect on inhibitory control was limited in the recent studies. These designs may ignore some conditions of children's effective learning, such as meaningful learning and social interaction (Hirsh-Pasek et al., 2015).

Considering the advantage of social interaction in a group setting, Tominey and McClelland (2011) developed circle time games to practice self-regulation in preschoolers. This intervention was effective for children with the lowest initial self-regulation levels (Tominey & McClelland, 2011) or from low-income families (Schmitt et al., 2015).

After that the researchers added other conditions for children's effective learning into EFs training games, such as using fictional characters to improve the child’s metacognition (Volckaert & Noël, 2015), using the same story and goal across all the games for children’s engagement, helping children organize the games autonomously for social interaction, and asking children to evaluate the effects of their performance in active learning (Traverso, Viterbori, & Usai, 2015). In the study by Volckaert and Noël (2015), training games based on a series of cognitive or body movement activities had impacted not only on inhibitory control and other EFs, but also on the behavioral changes with a decrease in external behavioral problems (Volckaert & Noël, 2015). The group games developed by Traverso et al. (2015)

had a significant training efficacy on inhibitory control of five-year-olds, such as the ability to delay gratification, control on-going responses, and interference suppression; additionally, this training improved pre-academic skills (Traverso, Viterbori, & Usai, 2019).

On the basis of previous studies, some key training principles can be identified to improve the efficacy of preschool inhibitory control training, such as self-adaptive difficulty, timely feedback, meta-cognition, community, interestingness, and comprehensiveness. Furthermore, Diamond (2013) stated that the advantages of EFs from training in the combined task (e.g., task switching) were much wider than in the single task of EF subcomponents (e.g., spatial working memory). Perhaps the coordination of the subcomponents plays a critical role in the training. The progressive design from the single game to the complex game may be essential for the training of inhibitory control. Nevertheless, to the best of our knowledge, no previous study has examined whether adopting these key principles in inhibitory training could enhance the effects on inhibition, and show improvement in other EFs, such as working memory and cognitive flexibility, and early academic skills.

Context of the Study

Based on the circle time games developed by Tominey and McClelland (2011), we can improve the training program for inhibition control by adding some key training principles to the design, such as interestingness (Traverso et al., 2015), adaptive difficulty, timely feedback, community, and meta-cognition (Volckaert & Noël, 2015). The present study aims to summarize and strengthen the key aspects of the inhibitory control training and evaluate the effects of improved group game training. Moreover, the improved training program was progressive; from simple games with a single rule to complex games with nested rules-switching. Therefore, we also verified the effects of the training on other EFs, which are closely related to inhibitions.

As one of the core EFs, inhibitory control is very important for the preschoolers' early academic skills. Studies have shown that inhibitory control of preschool children significantly predicts academic skills such as mathematical calculation, language consciousness, vocabulary knowledge (Allan et al., 2014; McClelland et al., 2007), and its effect on mathematics is stronger than the other two elements of EF: working memory and cognitive flexibility (Espy et al., 2004). However, there is relatively little research to examine the transfer effects of inhibitory control training on academic skills. Despite promising results seen in the studies by McClelland and colleagues in which self-regulation training, including inhibitory activities, allowed for improvement in letter-word identification (Tominey & McClelland, 2011) and math skills for preschoolers who were English language learners (Schmitt et al., 2015), no other studies have investigated the effects of inhibitory training based on group games on early academic achievement. Examining this issue will not only help to investigate the training-related benefits in real-life situations, but also directly test the causality of the relationship between inhibitory control and academic skills by manipulating inhibitory control. Therefore, this study investigated whether inhibitory training based on behavioral group games produced far-transfer effects on early academic skills.

In summary, this study was designed to examine the efficacy of inhibitory control training based on behavioral group games in a sample of preschoolers at immediate posttest as well as delayed posttest, which was conducted after a three-month gap. Additionally, the effects of training on other EFs skills and early academic achievement were also examined. The research questions and hypotheses are as follows:

First, could inhibitory training based on behavioral group games enhance inhibitory control in preschoolers? We expected that preschoolers who were randomly assigned to the training group would show significantly greater gains in inhibitory control than preschoolers in the control group at immediate and delayed posttests.

Second, could inhibitory training based on behavioral group games produce near-transfer effects on other EFs in preschoolers? We expected preschoolers in the training group to show significantly greater gains in working memory and cognitive flexibility than preschoolers in the control group at immediate and delayed posttests.

Third, could inhibitory training based on behavioral group games produce far-transfer effects on early academic skills three months after the training? We expected preschoolers in the training group to show not only gains in inhibitory control but also in receptive vocabulary and mathematical cognition. As the interval between pretest and immediate posttest was five weeks, we could only examine the training effects on early academic skills in the delayed posttest.

Materials and Methods

Participants

Fifty-one children aged between four and five years were recruited from a rare large-scale rural preschool in the local area in Changchun, China. We chose this preschool to engage participants who came from similar backgrounds, to avoid the influence of interference factors.

Before the study, written consent was obtained from the children's parents. The children were randomly assigned to either the training group or control group. The training group consisted of 24 children (13 girls and 11 boys, M_{age}±SD=4.60±0.30), with an average distribution of four subgroups. The control group consisted of 27 children (14 girls and 13 boys, M_{age}±SD=4.58±0.32). The children belonged mostly to less-educated families and their parents had completed only primary (mothers, 43.1%; fathers, 17.6%) or secondary education (mothers, 52.9%; fathers, 80.4%).

Measures

Inhibitory Control tasks

Three well-known measures of inhibitory control, different from the training activities, were used. These tasks required children to override a prepotent response to execute a rule-guided action and modify their actions in response to feedback (Finger-Fist task), stop an ongoing response (Stop-Signal Task), and to withhold a prepotent response and the provision of a novel response that is incompatible with the prepotent response (complex version of the Day-Night Stroop Task).

The Finger-Fist task. In this task (Hughes, 1998), the child was instructed to execute a rule-guided action First, the child was asked to make the same hand motion as the experimenter which meant when the experimenter made a fist (or pointed a finger), the child needed to make a fist (or pointed a finger). If the child made eight consecutive correct responses, he/she was asked to make the opposite hand motion as the experimenter (the conflict condition). And so, when the experimenter made a fist, the child needed to point a finger. There were 16 trials in a fixed sequence (fist - finger - fist - fist - finger - finger - fist - finger - finger - fist - fist - finger - fist - finger - fist- finger). The child received feedback on each trial. The performance in the conflict condition was taken as an index of inhibition control (0=wrong, 0.5=self-corrected, 1=correct).

The complex version of the Day-Night Stroop task. The Day-Night Stroop Task is a well-known measure of inhibitory control in younger preschoolers (Gerstadt, Hong, & Diamond, 1994). Considering the task-sensitivity, Day-Night Stroop task was complicated by adding nested rules in this study. That is, the complex version of the Day-Night Stroop task is the integration of the Day-Night Stroop paradigm and the Go/no-go paradigm. There are four different cards: “a sheep, the sun and clouds,” “a sheep, the moon and stars,” “a wolf, the sun and clouds,” and “a wolf, the moon and stars” (see Figure 1). “The sun and clouds” means “the day,” while “the moon and stars” means “the night.” If there is a sheep on the card (go trial), children must say the opposite of the meaning of the card as fast as possible (e.g., saying “night” for the card with “the sun and clouds,” saying “day” for the card with “the moon and stars”). If there is a wolf on the card (no-go trial), children had to say nothing.

[Figure 1 near here]

There were four practice trials and 16 test trials using the DMDX software (Forster & Forster, 2003). The sequence of each trial was as follows: first, the stimulus alert (+) appeared for 1000 ms; second, the stimulus appeared for 3000 ms; and finally, a white screen appeared for 500 ms. The child continued practicing until his/her accuracy was more than 1/2. In the test trials, each of the four cards was presented four times to children in a random order. The number of correct answers (including self-corrections) in response to the card with “a sheep” was recorded. Accuracy (number correct out of eight) was used as the outcome measure.

The Stop-Signal Task. This task (Pasalich, Livesey, & Livesey, 2010) was presented on a computer. The roads, red light, and garages were constant on the screen (see Figure 2). The child was instructed to respond according to the position of the car and the red light. The child had to press the left button if the car was on the left side of the road and the right button if the car appeared on the right side of the road. However, if the red light was on (the stop signal) after the car appeared (the go signal), the child did not have to press any buttons. The child had to respond as quickly and accurately as possible. If the reaction was correct, the car would drive into the corresponding garage accompanied by a “correct” tone and if the reaction was wrong, the car would disappear accompanied by a “raspberry” tone.

[Figure 2 near here]

Similar to a previous study (Pasalich et al., 2010), this task contained eight blocks. The first block was a baseline block, which contained only 12 go trials. The second block was a practice block and included 18 go trials and 6 stop trials. In the stop trials, the stop-signal delay (SSD), which is the time interval between the go and stop signals, was fixed (250 ms). The remaining six blocks were test blocks and they were similar to the practice block, in addition to the stop-signal delay. In the test blocks, the SSD was changed according to the performance of the child in the stop trials. If the reaction was correct, the SSD of the next stop trial was more difficult and lengthened by 50 ms. If the reaction was wrong, the SSD of the next stop trial was easier and reduced by 50 ms. The initial SSD was set at 250 ms, limited to the range between 0 and 1500 ms. The position of the cars was counterbalanced across blocks. For each trial, the stimulus alert (+) was displayed for 1000 ms, and the stimulus was displayed no more than 3000 ms. After the child responded, the feedback was displayed and lasted 1000 ms. The participant’s response to the test blocks was recorded. If the reaction time of the correct go trials was less than 500 ms (it is likely that the child does not have the consciousness to respond to stop-signals) or larger than 2500 ms (it is likely that the child is absent-minded during the reaction or deliberately slowed down to improve his accuracy) was discarded. The participant’s mean SSD of the stop trials and mean reaction times of the correct go trials (PTRT) was calculated. The stop-signal reaction time (SSRT) was calculated by subtracting the mean SSD from the mean reaction time (PTRT). A smaller SSRT indicated better inhibition control. Moreover, a shorter SSD indicated poorer accuracy. Accordingly, the larger ratio of SSRT to PTRT indicated a higher level of impulsivity.

Working Memory task

The Self-Ordered Pointing Task (Hongwanishkul, Happaney, Lee, & Zelazo, 2005) is used to assess the child's ability to update information in working memory. Besides the pattern of the item, the design and the implementation steps in this study were similar to the task in the previous study (Hongwanishkul et al., 2005).

In this task, there were nine blocks. Each block contained two different sets of trials. The number of trials in each set and the number of items in each trial were the same in each block, but the number of items increased from block 1 (two items) to block 9 (10 items). In each set of trials, the pattern of the items in each trial was the same, but the position was randomly changed from trial to trial (see Figure 3). The child was instructed to select one item in each trial and not to point to the same item twice. The first block was a practice block, and there were two items in each trial. If the child successfully completed two sets of trials in the practice block, he could continue with the remaining test blocks.

In test blocks, after the child passed the first set of trials, he/she would begin the next block. However, if the child did not pass, he/she was given the second set of trials. After passing the second set of trials, he/she would begin the next block. However, if the child did not pass, the task was terminated. The last block that the child passed indicated his/her working memory span.

[Figure 3 near here]

Cognitive Flexibility task

The Flexible Item Selection Task (FIST) was developed to measure the cognitive flexibility of preschoolers (Jacques & Zelazo, 2001). In this task, we added two practice trials, and the test materials consisted of 54 cards. Each card depicted a set of items, which were derived from a combination of four dimensions (shape, size, number, and color).

This task included one demonstration trial, four practice trials, and 12 test trials. In the demonstration trial and the first two practice trials, there were two pairs of cards in each trial, and four dimensions on the cards in each pair were identical. In the remaining two practice trials and the test trials, there were three cards in each trial. Two of the three cards had one dimension and a different pair of cards matched on the other dimension. For example (see Figure 4), P1_1 and P1_2 matched the dimension of the number, and P1_2 and P1_3 matched on the dimension of size. On each of these trials the children were instructed to make two selections. When they made the first selection, they were asked to perform the following, “Show me (put your fingers on) two cards that are the same in one way.” Once they responded, they were then asked the following, “Show me two cards that are the same but in a different way” (Jacques & Zelazo, 2001).

The placement of matching pairs was counterbalanced across test trials, and the cards were presented in the same order for all participants. The feedback was given to the child after the practice trials but not for the test trials. The mean accuracy of each test trail (the correct number of two selections out of the correct number of the first selection) was used as the measured outcome.

[Figure 4 near here]

Academic Skills tests

***Receptive Vocabulary test*.** The Peabody Picture Vocabulary Test-Fourth Edition (Dunn & Dunn, 2007) was used to assess the receptive vocabulary of preschoolers. Two hundred and twenty-eight items were divided into 19 sets, and each set consisted of 12 items. In each item, the child was verbally presented with one word and asked to point to the corresponding picture from four pictures in full color. If the child made eight or more errors in a set, the test was terminated. The raw score (the total errors out of the number of the ceiling items) represented the level of children's receptive vocabulary.

***Mathematical Cognition test*.** Based on Guideline to the Learning and Development of Children Aged 3–6 (2012), we developed a mathematical cognition test for preschool children, which included two subtests. The first subtest was used to assess the amount and quantitative relation, which consisted of object counting, fetching by number value, counting by number order, numbers comparisons, and simple calculations. The remaining four dimensions, except for the numbers comparisons, included two types of questions with different difficulty, depending on the range of numerical values (smaller than 5, or larger than 5 but smaller than 10). The second subtest was used to assess the shape and spatial relation, which consisted of position, geometry, and patterning/logical relations. If the child responded correctly he/she received a point, otherwise he/she did not receive it. The scores of the first subtest, the second subtest, and the total mathematical cognition test ranged from 0 to 5, 0 to 3, and 0 to 8. The relationships between each test item and the first subtest (r=.36~.81, n=118, p<.001), the second subtest (r=.36~.75, n=118, p<.001), and the total mathematical cognition test (r=.34~.75, n=118, p<.001) were all significant. The test difficulty ranged from .30 to .91, with an average difficulty of .70.

The mathematical cognition test has good reliability and validity (*CMIN/DF*=1.574, *CFI*=.960, *GFI*=.928, *RMR*=.026, *NFI*=.899, *TLI*=.949). The Cronbach's alpha coefficients in the amount and quantitative relation subtest, the shape and spatial relation subtest and the mathematical cognition test were 0.69 (n=6), 0.41 (n=5) and 0.74 (n=11) respectively. The relationships between the total mathematical cognition test and the first subtest and the second subtest were all significant (r=.93, .78, n=118, p<.001).

Procedure

Design

The study was divided into four phases: pretest, training, immediate posttest, and delayed posttest, conducted three months after the completion of the training. All the phases were implemented in the preschool. At the pretest, children completed baseline measures of basic components of EF (inhibitory control, working memory, and cognitive flexibility) and academic skills. Then, the children in the training group participated in group games for 30 minutes a day, three days a week, for five weeks, while the children in the control group watched cartoons or engaged in free play. To ensure training fidelity, a trainer was trained to administer the same training game on the same day to the four groups. In the immediate posttest, all children received the same EF tests as the pretest. In the delayed posttest, children were reassessed with EF tasks and academic skills tasks as the pretest. All the training games were different from the assessment tests. The children received a small gift after the final test.

Training

To promote inhibitory control in preschoolers, seven group games of body movements were developed: “The Circle Game,” “The Radish Game,” “The Bomb Avoidance Game,” “The Flying Game,” “The Swimming Game,” “Monster, what time is it?” and “Head-Toes-Knee-Shoulder Game” (see Supplementary Material). The training design in this study included six key training principles:

Using fantasy story and characters to connect all sessions. To present the meaningfulness and interestingness of the group games, we drew lessons from a fantasy story by Traverso et al. (2015). In this story, two small goblin friends, Chicco and Nanà, erroneously transform themselves into a mouse and a cat, respectively. To revert this they need to overcome different challenges. The children were asked to help Chicco and Nanà by overcoming different challenges (training games) that require inhibitory control. The importance of this design lies in three aspects. First, the fantasy story and characters help in increasing the interestingness of the group games. Second, helping others is conducive to inspiring and maintaining children’s game motivation and meaningfulness. Third, using the same story and characters to connect all the sessions helps children to keep working hard and adjust their present or future performance to their previous performance.

Setting up different difficulty levels for the training games. There were different difficulty levels in the training sessions. Before starting the next game with different difficulties, every child in the small group had to pass the easier game. The difficulty level of the game was manipulated by shortening the available reaction time and increasing the complexity of training games, such as gradually increasing the nested rules, increasing the frequency of rules switching, adding interference stimulation, and changing from a single instruction to sequences of instructions, and so on. Along with the training, the difficulty and complexity of games gradually increased. And so, the training games included simple inhibitory control games during early training and complex inhibitory control games during later training, and it was progressive from simple to complex. Simple skills were necessary for complex skills, and complex skills were helpful for gaining simple skills.

Giving visual feedback on the performance of preschoolers. The feedback design included immediate feedback from the experimenter, supervision and inspection from game partners, gain or loss of tokens, and so on. Before the game started, the experimenter introduced the feedback table with the names of children which showed the feedback on their performance and their respect for the game’s rules. If the child's performance was correct, he/she would win a red token under his/her name in the feedback table. However, if the child's performance was wrong, he/she would lose a red token. Similarly, if the child respected the game rules, he/she would win a yellow token, otherwise lose a yellow token. More tokens meant greater rewards. There were three types of rewards: participation rewards (small stickers) for every participant, the Today's Star rewards (police or detective medals, and chocolate candies) for two children who performed best on that day, and summative rewards (Lego dolls or little lollipops -10 tokens, big lollipops - 20 tokens, plush toys - 40 tokens) for the exchange of tokens based on their preferences. At the end of each game, the experimenter would tell the children about the number of tokens each of them had earned and encourage them to delay the exchange for the bigger rewards.

Emphasizing the model's demonstration and cooperation. The division of group members followed the principle of heterogeneous and homogeneous grouping. Based on the children's ranking in inhibitory control performance in pretests, the heterogeneous group in the early seven training sessions included children with different levels of inhibition control, and the homogeneous group in the later eight training sessions included the children with similar levels of inhibition control (see Table 1). The simple versions of seven group games were separately implemented in the early seven training sessions, and the complex versions were separately implemented in the later eight training sessions. To promote interaction among children, we drew lessons from the design in the study by Traverso et al. (2015). The experimenter helped the group members to manage and control the game autonomously. Each child was given a role with a specific responsibility, and the roles were exchanged during the game. All of the games were structured in three sessions. First, the experimenter organized the collective activity to introduce the game. Second, the showtime for each child was decided which was helpful in enhancing his/her understanding of the game roles. Finally, the children managed and controlled games, and the experimenter would provide suggestions and support, if necessary.

[Table 1 near here]

Enriching the metacognitive activities. On the basis of fore studies, the metacognitive designs were in the following four aspects. First, self-monitoring skills such as carefully looking, listening, and thinking (i.e., Traverso et al., 2015), were integrated into children's songs, and practiced in each game. Second, specific characters such as policeman, detective, and statue (Volckaert & Noël, 2015), were used to provide models for children, which was conducive to reminding the children to follow the game rules. Thirdly, they discussed their performance as well as of others. At the end of each game, the experimenter would encourage children to reflect on their performance and discuss how to perform better. This helped promote children's self-evaluation and regulation. The number and color of tokens for each child could reflect his/her specific performance during and at the end of each game. It helped each child to realize his/her strengths and weaknesses.

Setting up aided designs to conduct the games smoothly. First, create a game atmosphere of encouragement and collaboration; second, set down clear and concrete game rules, and finally, provide scaffolded instruction to help children follow the rules. For example, physical materials, such as the cards of eyes, ears, and mouth, would provide concrete aids to help children play games in turn.

AssessmentProcedure

Postgraduates majoring in preschool education were recruited as the experimenters and they received training before the test implementation. The experimenters were blinded to the children's conditions (training/control group), and each experimenter participated in the test during only one of the phases, either pretest, posttest, or delayed posttest. Children were tested individually in a quiet room at the preschool. The pretest included EFs and academic skills tasks that were completed in three sessions within one week. The posttest included EF tasks that were completed in two sessions within one week. The delayed posttest was the same as the pretest. Each testing session lasted no more than 30 minutes per child.

Statistical analyses

Statistical analyses were performed using IBM SPSS Statistics, version 16.0 for Windows. There were two steps. First, *t*-tests were used to examine the initial differences between the control group and training group in the pretest. Second, the repeated measures ANOVAs and *t*-tests were used to examine the training effects. The level of significance for all tests was set at .05. Additionally, effect sizes were reported.

Results

Between-Group Comparisons in the Pretest

The mean scores and standard deviations in tests for the control group and the training group are reported in Table 2. The *t*-tests were used to examine the initial differences between the two groups in terms of demographic variables, inhibitory control variables, working memory, cognitive flexibility, and early academic skills. However, no statistically significant differences were found. Therefore, we can assume the groups to be sufficiently equivalent in the pretest.

Training Effects on Inhibitory Control

To measure the effectiveness of the training on inhibitory control, we calculated four

3×2 repeated-measures ANOVAs with one within-subject factor, time (pretest, immediate posttest, and delayed posttest), and one between-subjects factor, group (the control group and the training group).

[Table 2 near here]

The 3×2 repeated-measures ANOVA on the accuracy of the Finger-Fist task showed a significant time-by-group interaction [F (1, 40) = 5.36, $p < .05$, $\eta_p^2 = .12$] and the main effect of time [F (1, 40) = 15.36, $p < .001$, $\eta_p^2 = .28$], but the main effect of group was not found [F (1, 40) = 3.15, $p = .08$]. The simple effect analysis showed that the training group significantly improved from pretest to immediate posttest and delayed posttest ($F = 15.24$, $p < .001$), which was not the case for the control group ($F = .76$, $p > .05$). The difference between the control and training groups was not significant in pretest ($F = .85$, $p > .05$, $d = -.08$), but was significant in the immediate posttest ($F = 6.05$, $p < .05$, $d = .77$) and delayed posttest ($F = 6.30$, $p < .05$, $d = .72$) (see Figure 5).

The 3×2 repeated-measures ANOVAs on the other inhibitory control indicators showed no significant time-by-group interaction, which were the accuracy of the Complex Day-Night Stroop task [F(1, 38) = 2.24, $p = .14$], the SSRT [F (1, 40) = .36, $p = .55$] and the ratio of the SSRT to the mean reaction time [SSRT/PTRT, F (1, 40) = .55, $p = .46$]. To measure the immediate effectiveness of the training on inhibitory control, we then calculated three 2×2 repeated-measures ANOVAs with one within-subject factor, time (pretest and immediate posttest), and one between-subjects factor, group (the control group and the training group) (see Figure 5).

[Figure 5 near here]

The 2×2 repeated-measures ANOVAs on the accuracy of the Complex Day-Night Stroop task showed a significant main effect of time [$F(1, 38) = 13.72$, $p < .01$, $\eta_p^2 = .22$], and no main effect of group [$F(1, 38) = .65$, $p = .42$], but a marginal time-by-group interaction [$F(1, 38) = 4.03$， $p = .051$， $\eta^2 = .087$]. The independent-samples of *t*-test (see Table 2) indicated that the difference between the control group and the training group was not significant in the pretest ($t = .35$, $p > .05$, $d = -.11$), but showed a trend in the immediate posttest ($t = -2.02$, $p = .052$, $d = 0.59$). The paired-samples *t*-test indicated that the training group significantly improved from pretest to immediate posttest ($t = 3.93$, $p < .05$, $d = 0.85$), which was not the case for the control group ($t = -1.24$, $p > .05$, $d = .22$).

The 2×2 repeated-measures ANOVAs on the SSRT showed a significant main effect of time [$F(1, 38) = 38.57$, $p < .001$, $\eta_p^2 = .22$], and no main effect of group [$F(1, 38) = 1.57$, $p = .22$] but a marginal time-by-group interaction [$F(1, 38) = 3.07$, $p = .087$， $\eta^2 = .067$]. The paired-samples of *t*-test indicated that the SSRT of the training group significantly shortened from pretest to immediate posttest ($t = -6.41$， $p < .001$, $d = -1.55$), and the SSRT of the control group also significantly shortened from pretest to immediate posttest ($t = -2.87$, $p < .01$, $d = -.52$). However, the decrease in the SSRT in the training group was greater than that in the control group.

The 2×2 repeated-measures ANOVAs on the ratio of the SSRT to the mean reaction time (the level of impulsivity) showed a significant main effect of time [$F(1, 38) = 18.99$, $p < .001$, $\eta_p^2 = .22$], but a marginal main effect of group [$F(1, 38) = 3.53$, $p = .067$, $\eta_p^2 = .076$]

and time-by-group interaction [$F(1, 38) = 2.95$, $p = .093$, $\eta^2 = .064$]. The independent-samples of the *t*-test indicated that the difference between the control and training groups was not significant in the pretest ($t = -1.14$, $p > .05$, $d = -.30$), but was significant in the immediate posttest ($t = -2.12$, $p < .05$, $d = -.53$). The paired-sample *t*-test indicated that the training group significantly shortened from pretest to immediate posttest ($t = -3.92$, $p < .01$, $d = -.92$), which was a marginal effect of the control group ($t = -2.07$, $p = .051$, $d = -.32$). The decrease in the level of impulsivity in the training group was greater than that in the control group.

Training Effects on Working Memory and Cognitive Flexibility

To measure the effectiveness of training on working memory and cognitive flexibility, we calculated two 3×2 repeated-measures ANOVAs with one within-subject factor, time (pretest, immediate posttest, and delayed posttest), and one between-subjects factor, group (the control group and the training group).

The 3×2 repeated-measures ANOVA on the working memory showed a significant main effect of time [$F\ (1, 40) = 64.57$, $p<.001$, $\eta_p^2 = .62$] and time-by-group interaction [$F\ (1, 40) = 6.63$, $p < .05$, $\eta_p^2 = .14$], but no main effect of group [$F\ (1, 40) = 2.43$, $p = .13$]. The simple effect analysis showed that all children significantly improved from pretest to immediate posttest and delayed posttest ($F_t = 38.99$, $p < .001$; $F_c = .76$, $p >.05$). The difference between the control group and the training group was not significant in the pretest ($F = 0.94$, $p > .05$, $d = -0.25$), but was significant in the immediate posttest ($F = 6.03$, $p < .05$, $d =.86$) and delayed posttest ($F = 4.76$, $p < .05$, $d = .48$). The improvement in working memory in the training group was greater than that in the control group (see Figure 6).

[Figure 6 near here]

The 3×2 repeated-measures ANOVA on the accuracy of the Flexible Item Selection task showed no significant time-by-group interaction [$F(1, 40) = 2.56$, $p = .12$]. The 2×2 repeated measures ANOVA with one within-subject factor, time (pretest and immediate posttest) and one between-subjects factor, group (the control group and the training group) showed a significant main effect of time [$F(1, 38) = 20.67$, $p < .001$, $\eta_p^2 = .22$], no main effect of group [$F(1, 38) = 1.67$, $p = .20$], but a marginal time-by-group interaction [$F(1, 38) = 2.90$, $p = .096$, $\eta_p^2 = .063$] (see Figure 6). The independent-samples *t*-test indicated that the difference between the control group and the training group was not significant in the pretest ($t = -.37$, $p > .05$, $d = -.07$) and immediate posttest ($t = 1.80$, $p > .05$, $d = 0.54$). The paired-samples of *t*-test indicated that the training group significantly improved from pretest to immediate posttest ($t = 4.59$, $p < .001$, $d =.93$), but there was only a marginal effect on the control group ($t = 1.95$, $p = .064$, $d =.35$). The improvement in cognitive flexibility in the training group was greater than that in the control group.

Training Effects on Early Academic Skills

In this study, all children completed the tests of early academic skills in the pretest and delayed posttest. To measure the effectiveness of the training on early academic skills, we calculated four 2×2 repeated-measures ANOVAs with one within-subject factor, time (pretest and delayed posttest), and one between-subject factor, group (the control group and the training group).

The repeated-measures ANOVA on the level of *receptive vocabulary* and the level of *the shape and spatial relation* showed marginal time-by-group interaction [F (1, 45) = 3.84, 2.97, p = .056, .09, η_p^2 = .079, .062]. The paired-samples of t-test indicated that the training group and the control group both significantly improved from the pretest to the retention test (t_t = 8.69, 6.04, p < .001, .001, d_t = 1.28, .75; t_c = 4.89, 2.83, p < .001, .01, d_c = .86, .59), but the improvement in the level of *the shape and spatial relation* of the training group was greater than that in the control group (see Figure 7).

[Figure 7 near here]

The repeated-measures ANOVA on the level of *mathematical cognition* and the level of *the amount and quantitative relation* showed no significant time-by-group interaction [F (1, 45) = 2.69, .33, p = .11, .57]. The independent-samples of t-test indicated that the difference between the control group and the training group was not significant in the pretest (t = .67, 1.48，p > .05, d = .19, .42), but was significant in the retention test (t = 2.97, 2.12, p < .01, .05, d = .88, .61). The paired-samples t-test indicated that the training group and the control group both significantly improved from the pretest to the retention test (t_t = 7.47, 3.87, p < .001, .01, d_t = 1.30, 0.76; t_c = 3.70, 2.56, p < .01, .05, d_c = .91,.57) (see Figure 7). The improvement in the level of *mathematical cognition* and the level of *the amount and quantitative relation* in the training group was greater than that of the control group.

Discussion

The preschool years are a crucial stage for the training of inhibitory control. In recent years, various types of EFs training have emerged. However, only limited studies have examined the effect of training on inhibitory control. The few studies that focused on inhibitory control training did not evaluate the lasting training effect and the transfer effect on early academic skills. Based on existing training related designs, this study optimized the program and developed seven group games with different difficulty levels. It also evaluated the training effect on inhibitory control, other EF subcomponents, and early academic skills in the immediate posttest and the delayed posttest, conducted three months after the training ended.

Training Effects on Inhibitory Control

A variety of inhibitory control indicators were used in this study, including accuracy of the Finger-Fist task and the Complex Day-Night Stroop task, the SSRT, and the ratio of the SSRT to the mean reaction time (the level of impulsivity). The results confirmed the training effect.

This group game training could significantly improve the preschoolers' performance in the stop-signal task. This is different from the effects of existing training. In the study by Thorell et al. (2009), computerized training of inhibitory control could not improve the preschoolers' performance in the Stop-Signal task, which was the training task. However, in this study, group training based on behavioral games could significantly improve the preschoolers' performance in the Stop-Signal task, which was not the training task. This may be due to several reasons. First, the training forms were different. The effect of group games based on body movements may be better than the effect of computerized training. Second, the game difficulty in our study was more diverse. It was manipulated not only by shortening the available reaction time, but also by increasing the complexity of training games, such as gradually increasing the nested rules, increasing the frequency of rules switching, adding interference stimulation, and so on. We also divided participants into homogeneous groups by their inhibition control level in the later eight training sessions, which was helpful to challenge them in their proximal zone of development. Third, some key training principles, such as metacognition, were added to our training design which might have affected the result. Metacognitive designs would help in encouraging self-reflection and self-evaluation.

In contrast to previous research, this study also analyzed the training effect on impulsivity level, which is the ratio of the SSRT to the mean reaction time (SSRT/PTRT). A smaller ratio (SSRT/PTRT) reflects that the child thinks carefully before his/her reaction. That is, the child is less impulsive. This study found that the decrease in the ratio of the SSRT to mean reaction time (SSRT/PTRT) in the training group was greater than that in the control group.

Besides the Stop-Signal task, this group game training could also significantly improve preschoolers' performance on the Complex Day-Night Stroop task and the Finger-Fist task. However, in the Finger-Fist task, the lasting effect for three months after training was significant. This could be due to the similarity of the design of the Finger-Fist task to that of the training games, in which the children needed to regulate their body movements more often. Therefore, the design could be further optimized to enhance the training effect.

Training Effects on Working Memory and Cognitive Flexibility

Although the training games in this study focused on inhibitory control, we also expected improvements in working memory and cognitive flexibility after training. The results are in line with our expectations.

This group game training significantly improved the preschoolers' working memory, and the lasting effect for three months after the end of training was also significant. This is similar to the results of previous studies. In the study by Volckaert and Noël (2015), the training games were aimed at increasing the different components of inhibitory control, but there was a transfer to working memory. In the study by Traverso et al. (2015), small group games that required progressively higher levels of inhibitory control, working memory, and cognitive flexibility, significantly improved the preschoolers' working memory. The main reason is that inhibitory control and working memory are closely related. Withholding information in mind would help in inhibitory control. Resisting irrelevant things or ideas would help protect the mental workspace for working memory (Diamond, 2013). The improvement of inhibitory control is bound to be accompanied by an improvement in the working memory. Moreover, the training games in this study included the complex inhibitory control games that required the children to remember different rules. The training effect on working memory may be partly due to direct exercise.

This group training could significantly improve the preschoolers' cognitive flexibility, but the lasting effect at three months after training was not significant. On one hand, this may be because the training games in this study focused on inhibitory control, and so, the transfer effect was limited. On the other hand, it may be due to the different points between the training and the test indicators. Cognitive flexibility was divided into the goal representation aspect and the actual switch-implementation process (Brocki & Tillman, 2014). In previous studies, the cognitive flexibility tasks were mainly the switch implementation process, such as the Dots task (Traverso et al., 2015) and the mixed condition of traffic lights task (Volckaert & Noël, 2015). This study used the Flexible Item Selection task to test the goal representation process, which needed children to match cards to abstract the dimension (e.g., size). Although the combined training games which needed the coordination of EF subcomponents were included, they were mainly rule switching games, inclined to the actual switch-implementation process. That is, this group training significantly improved the preschoolers' goal representation, but the lasting effect was not significant. The transfer effect of this group training on cognitive flexibility has to be improved.

Training Effects on Early Academic Skills

Inhibitory control plays a crucial role in both preliteracy skills (e.g., phonological awareness, letter knowledge) and early math skills (Allan et al., 2014; Blair & Razza, 2007). This study tested the effects of inhibitory control training on early academic skills of preschoolers three months after the training ended. In addition to the Receptive Vocabulary test, the early academic skills tests were also included in the Mathematical Cognition test, which was developed by the guidelines for the learning and development of Chinese preschoolers. The results indicated that group training could improve preschoolers' mathematical cognition, but not receptive vocabulary.

This could be owing to the fact that the role of inhibition control for mathematical cognition is more substantial than that of receptive vocabulary. The research evidence demonstrated that EFs were stronger or have more consistent associations with mathematical skills relative to reading or language-related skills during the preschool years (Blair & Razza, 2007; Son, Choi, & Kwon, 2019). Different cognitive demands from mathematical to language-related tasks might result in different associations (Son et al., 2019). Neuroscientific research has demonstrated that the parietal-frontal cortical circuitry is the overlap neural basis of EF, numerical ability, and quantitative reasoning (Klingberg, 2006). Similarly, neurons tuned to specific numerosities in prefrontal and parietal cortical areas have been identified by using single-unit physiology with nonhuman primates (Blair & Razza, 2007; Nieder, 2005). Therefore, if the inhibition control was improved, mathematical cognition also improved.

Moreover, researchers speculated that language-related covariance may influence the associations between EFs and reading measures (Son et al., 2019). However, group games based on body movement were mainly non-language-based games. The effects of training on receptive vocabulary may be a long-term effect. As the level of inhibitory control improves, the ability of children to successfully regulate their learning-related behavior, including paying attention, remembering instructions, and completing tasks (McClelland et al., 2007) improves. However, three months may not be sufficient.

Evaluation of the Small Group Training

As stated above, the optimized group training resulted in positive effects on the development of children's EFs and early academic skills, confirming its efficacy. The advantages of this group training lie in two aspects. First, this group training was a summary of existing training, which integrated key training principles in previous training studies.

These key training principles included small group training (i.e., six persons in each group), increasing the meaningfulness and interestingness of training games, setting up different difficulty levels for the training games, giving visual feedback for performance, enriching the metacognitive activities, creating an encouraging and supporting game atmosphere, setting up aided designs for the games to go on smoothly, and so on.

Second, this group training was developed from the existing training, which gradually added the combined games that needed the coordination of EF subcomponents. After the preschoolers gained specific skills through simple inhibitory control games, the combined games were implemented. When they practiced complex skills, specific skills (e.g., inhibitory control) would also improve.

The small group training was mainly limited to the number of training games. These training games were adapted from interesting games which matched the developmental trait of preschoolers' body and mind, such as “Wolf, Wolf, what time is it?” Although this training program had a significant effect, it only included seven group games. In the future, it is necessary to screen the games commonly used in preschools and adapt these interesting games to the training games.

Limitations and Future Directions

Through a variety of measurement indicators, this study examined the training effect of group games based on body movements. This is an important guiding significance for the cultivation of inhibitory control in preschoolers. Nevertheless, several limitations of this study should be noted.

The training design needs to be improved. First, it is necessary to increase the training time. In this study, the training lasted for five weeks. Although there were 15 activities and the training effects on EFs and early academic skills were significant, increasing the training duration may help in enhancing the training effects. Second, it is necessary to add an active control group. Through the comparison of the training group with only the passive control group, it was difficult to demonstrate the training effect. Third, it is necessary to optimize the test tools and enrich the test contents. Although the mathematical cognition test has good reliability and validity, the Cronbach's alpha level for the shape and spatial relation subtest was quite low. Additionally, Zelazo and Müller (2002) distinguished between two aspects of EFs—the “cool” cognitive aspects and the “hot” affective aspects. The “cool” EFs are more associated with dorsolateral regions of the prefrontal cortex and more likely to be elicited by abstract, decontextualized problems (e.g., Self-Ordered Pointing task). The “hot” EFs are more associated with ventral and medial regions and are more likely to be elicited by problems that involve the regulation of effect and motivation (i.e., Delay of Gratification task) (Hongwanishkul et al., 2005). Our measures are limited to the “cool” EFs. For the better popularization of this group training, it is necessary to explore the training effects on “hot” EFs (e.g., emotion regulation, delay gratification), social relationships and behavior problems in future studies.

Furthermore, the training environment needs to be improved. In this study, the training games were carried out by a trained experimenter, and the participants only involved children. There was a lack of training intervention for teachers and parents who affect the microenvironment of preschool children. Understanding the importance of knowing the training implementation, future research should also add teacher training to increase the effectiveness and generalizability of inhibitory control training. Training games administered by teachers are required.

Conclusion and Implications

Inhibitory control grows rapidly in the preschool period and has crucial predictive effects on early academic skills. This study aimed to improve the training program for inhibitory control and examine the training effect. As assumed, the optimized group training could obviously improve inhibitory control, working memory, and cognitive flexibility in immediate posttests, and inhibitory control, working memory, speech comprehension, and mathematical cognition in the delayed posttests.

To improve social and cognitive adaptation of preschoolers, sufficient attention should be paid to the cultivation and promotion of EFs. Group game training for inhibitory control in this study, which is suitable for preschoolers, is an effective method. Therefore, these group activities should be combined in developing curricula for rural preschool education. Although the number of training games was limited, educators could develop similar inhibitory control activities based on the training principles, such as interestingness, adaptive difficulty, timely feedback, community, and meta-cognition. It is meaningful for educators to address inhibitory control throughout the day.

Declaration of interest

No potential competing interest was reported by the author(s).

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Table 1

The children's ranking number of inhibitory control performance in pretests for the Heterogeneous Groups or the Homogeneous Groups

	Heterogeneous Groups (in the early 7 training sessions)	Homogeneous Groups (in the later 8 training sessions)
Group 1	R_{1}~R_{3}， R_{13}~R_{15}	R_{1}~R_{6}
Group 2	R_{4}~R_{6}， R_{16}~R_{18}	R_{7}~R_{12}
Group 3	R_{7}~R_{9}， R_{19}~R_{21}	R_{13}~R_{18}
Group 4	R_{10}~R_{12}， R_{22}~R_{24}	R_{19}~R_{24}

Table 2

Mean scores and standard deviations for each group in test sessions and between-group comparisons

Variables	**Pretest** Control Group M(SD)	Training group M(SD)	Analysis t(*p*)	**Immediate posttest** Control group M(SD)	Training group M(SD)	Analysis t(*p*)	**Delayed posttest** Control group M(SD)	Training group M(SD)	Analysis t(*p*)	Analysis Group by time interaction F(*p*)	Partial eta squared (η^2_p)
Demographic data											
Sex(% man)	48.15%	45.83%									
Chronological age(in years)	4.58(.32)	4.60(.30)	-.16(.88)								
Mother education(max-4)	1.58(.58)	1.70(.56)	-.73(.70)								
Father education(max-4)	1.85(.46)	1.83(.39)	.16(.87)								
Family income(max-4)	2.65(1.09)	2.35(1.23)	.92(.36)								
Inhibition Control											
Finger-Fist accuracy	.80(.11)	0.79(.16)	.38(.71)	.83(.16)	.93(.09)	-2.50(.02)	.86(.12)	.93(.07)	-2.39(.02)	5.36(.03)	0.12
CDNSA①	.73(.24)	0.70(.29)	.35(.73)	.78(.23)	.90(.18)	-2.02(.05)	.79(.19)	.86(.14)	-1.40(.17)	2.24(.14)	
SSRT(ms)	1008.17(126.38)	1016.43(94.56)	-.26(.80)	936.04(155.00)	864.11(106.28)	1.81(.08)	919.42(117.27)	892.73(126.88)	.75(.46)	.36(.55)	
SSRT/PTRT	.70(.08)	0.68(.05)	1.14(.26)	.67(.11)	.62(.08)	2.12(.04)	.65(.07)	.61(.09)	1.83(.07)	.55(.46)	
Working memory											
Working memory span	5.22(1.76)	4.79(1.72)	.88(.38)	6.00(1.48)	7.27(1.52)	-2.85(.007)	7.00(1.56)	7.78(1.76)	-1.62(.11)	6.63 (.01)	0.14
Cognitive Flexibility											
Cognitive Flexibility Accuracy	.62(.12)	0.61(.16)	.37(.71)	.67(.17)	.76(.17)	-1.80(.08)	.87(.14)	.92(.10)	-1.55(.13)	2.56(.12)	
Early academic skills											
PPVT™-4	65.27(21.00)	61.17(20.34)	.70(.49)				81.42(17.23)	83.00(14.04)	-.35(.73)	3.84(.56)	.08
The shape and spatial relation accuracy	1.92(.65)	1.78(.76)	.70(.49)				2.29(.62)	2.58(.41)	-1.93(.06)	2.97(.09)	.06
The amount and quantitative relation accuracy	3.23(.91)	3.58(.76)	-1.48(.15)				3.69(.72)	4.10(.64)	-2.12(.04)	0.33(.57)	
Mathematical Cognition accuracy	5.15(1.04)	5.36(1.22)	-.67(.51)				5.98(.81)	6.69(.84)	-2.97(.01)	2.69(.11)	

Note： CDNSA①=Complex Day-Night Stroop accuracy.

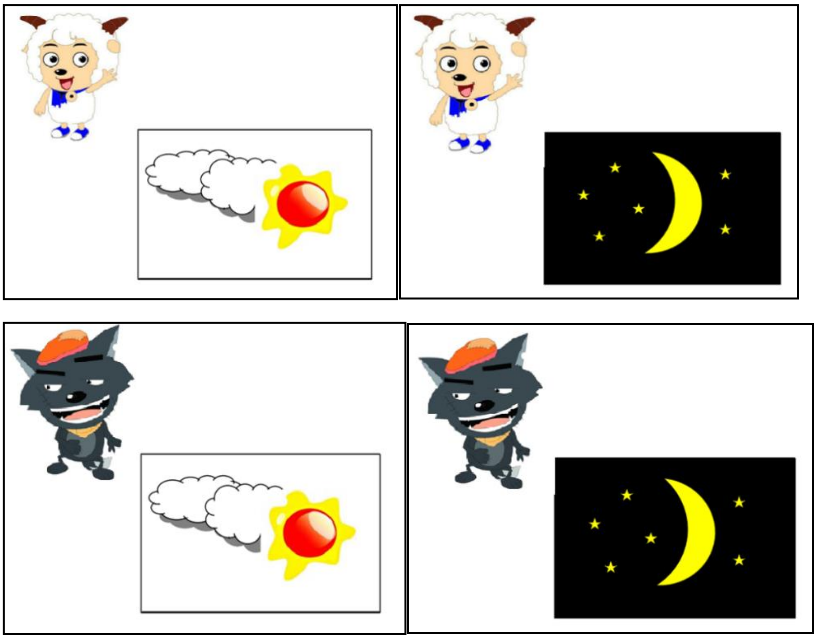

Figure 1. Four kinds of cards in the complex version of the Day-Night Stroop task.

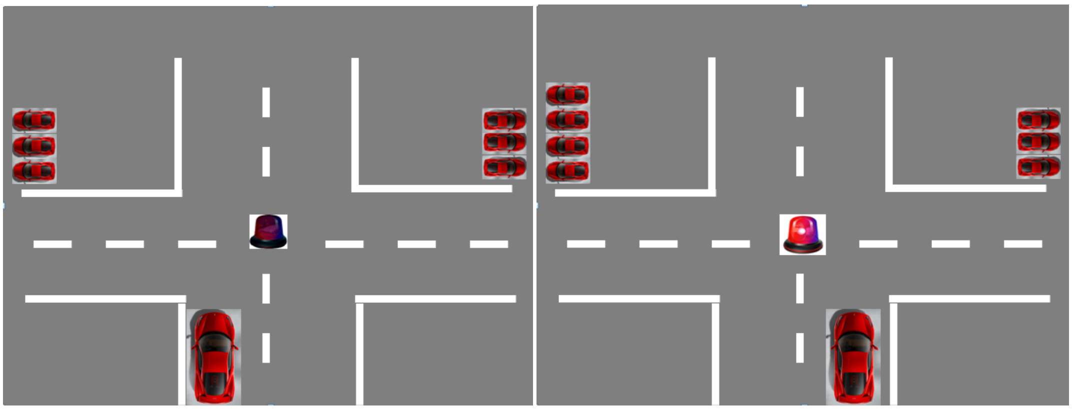

Figure 2. The interface of the Stop-Signal task(the go signal trial on the left and the stop signal trial on the right).

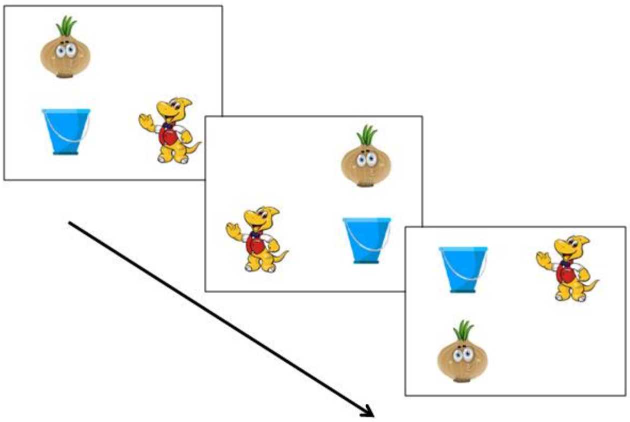

Figure 3. The interface of the Self-Ordered Pointing Task(n=3).

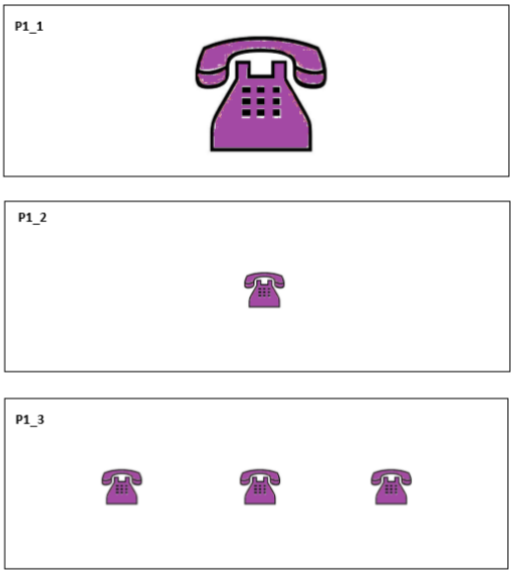

Figure 4. The cards of one practice trial in the Self-Ordered Pointing Task.

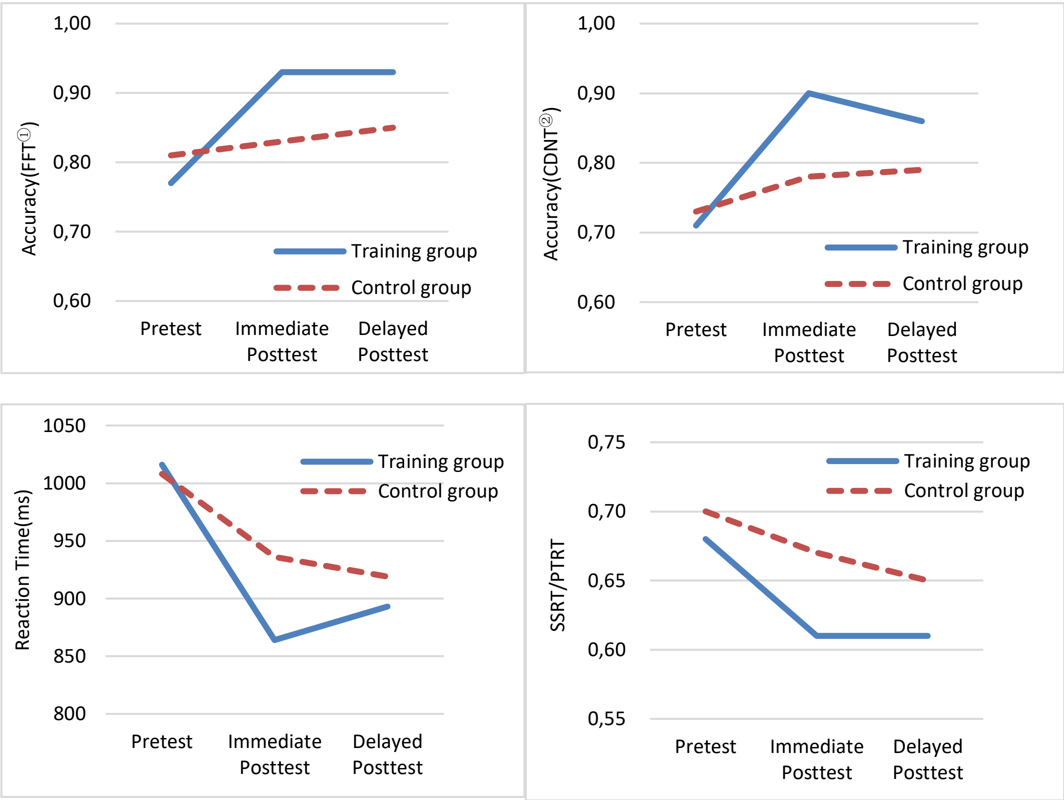

Figure 5. Impact of the training on inhibitory control

(① the Finger-Fist task; ②the Complex Day-Night Stroop task).

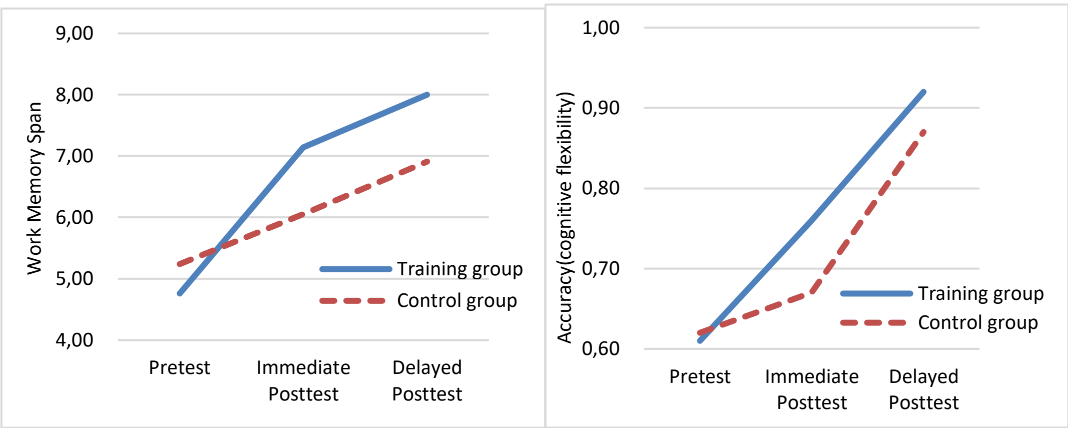

Figure 6. Impact of the training on working memory and cognitive flexibility.

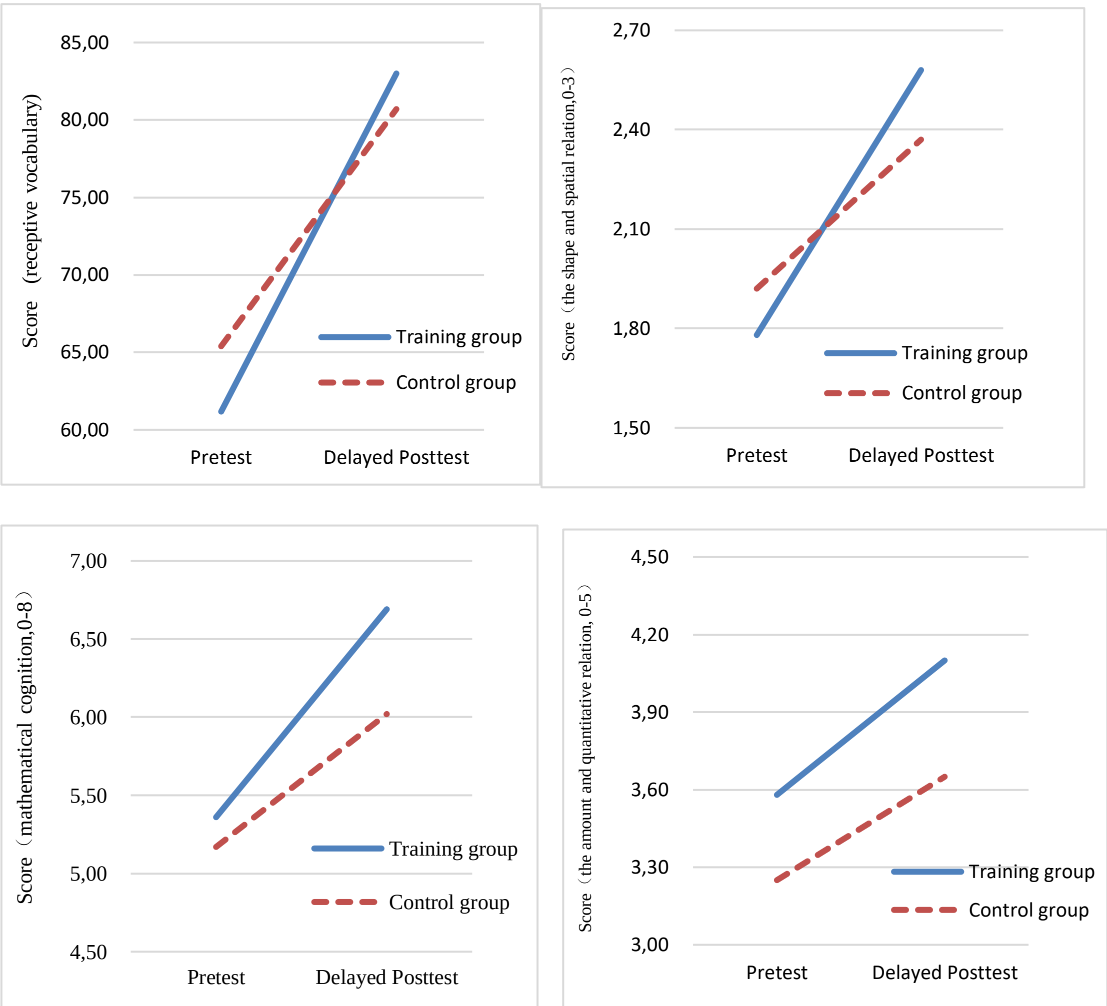

Figure 7. Impact of the training on early academic skills.