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**Multi-dimensional assessment of pretend-play training for pre-schoolers: from behavioural self-regulation to the neural underpinning of underlying executive function. How well does playing support development?**

**Nicolas Adam<sup>1,2\*</sup>, Agnès Blaye<sup>2,3</sup>, Rasa Gulbinaite<sup>4,5</sup>, Sylvain Chabe-Ferré<sup>6</sup> & Chloé Farrer<sup>1,2</sup>**

<sup>1</sup> Université de Toulouse, Centre de recherche Cerveau et Cognition, Toulouse, France

<sup>2</sup> Centre National de la Recherche Scientifique, France

<sup>3</sup> Université Aix-Marseille, Laboratoire de Psychologie Cognitive, UMR 7290, Marseille, France

<sup>4</sup> Université de Lyon, Centre de Recherche en Neurosciences, Lyon, France

<sup>5</sup> Institut National de la Santé et de la Recherche Médicale U1028, Lyon, France

<sup>6</sup> Institut of Advance Sciences of Toulouse, Toulouse, France

**\* Corresponding Author:**

[nicolas.adam@cnrs.fr](mailto:nicolas.adam@cnrs.fr)

(+33) 562 744 581

(+33) 674 771 091

Orcid ID : 0000-0001-6193-1472

Brain and Cognition Research Center

CNRS CERCO UMR 5549

Pavillon Baudot

CHU Purpan

1, place du Dr. Baylac

BP 25202

31052 Toulouse Cedex

## **Abstract**

Despite these results it allows us to advance in the understanding of efficient approaches for training ef , their underlying brain mechanisms and their impact on the child socioemotional functioning

**Keywords:** Pretend Play Training, Cognitive control, EEG Theta power, preschool, conflict, interference

### Highlights

- Self-regulation involves the implementation of a wide range of skills (cognitive control, socio-emotional skills and metacognitive skills) in order to behave in an adapted manner in a particular contextual situation.

## **Introduction: Selfregulation scaffolding through executive function training during the preschool years**

Self regulation correspond to the ability to comply with rules, to regulate our emotions and to behave in socially appropriate ways (Carlson and Moses 2001; Hughes and Ensor 2007; Raver et al. 1999; Sokol et al. 2010, Blair and Raver, 2015). Effective self-regulatory skills promote positive interactions with others and thus contribute to school readiness (Blair 2002; Raver 2004). The development of self-regulation enables children to improve their ability to act and think deliberately, through the coordination of their emotions, attention, feelings and actions (Eisenberg and Zhou, 2016; Nigg, 2017). Self-regulation draws in part upon executive functions (Jones, 2016; Nigg, 2017; Bayley and Jones, 2019), a set of partially independent top-down cognitive processes that support goal-directed behavior (Banich et al., 2019; Diamond, 2013; Miyake et al., 2000). Executive functions are also involved in self-regulation by their link with other capacities such as the metacognitive skills (i.e. self-monitoring, self-assessment) and the socio-emotional skills (i.e. theory of mind, empathy), a set of skills that help control behaviour.

Executive functions are important for many aspects of the child's everyday functioning and school success. In the preschool ages, early individual differences in executive functioning partly explain differences in school readiness (Lewit & Baker, 1995; Blair, 2002; McClelland, Cameron, Wanless, and Murray, 2007) as well as later academic achievement (Blair and Razza, 2007 ; McClelland et al., 2007; Espy et al., 2004, ; Howse et al., 2003). These associations are explained by the involvement of executive functions in academic learning skills (St. Clair-Thompson and Gathercole, 2009; Waber et al., 2006; Bull & Scerif, 2001). Children with poorer executive skills have greater risk to fall behind as soon as they enter school (Blair, 2002; Mclelland et al., 2000). There is therefore a great interest in helping children developing their executive functioning before school entry to enhance their self-regulation skills and limit the achievement gap they could later have.

This interest is even more important for children facing poverty, given the accumulating evidence that poverty-related gaps in school achievement are partly explained by the detrimental effects of poverty on child's self regulation development (Evans and Rosenbaum, 2008, O'Shaughnessy et al., 2003). However, what interventions and training programs promote the development of executive functions in ways that also benefit children's academic

and socioemotional competences remains an open question (Diamond and Ling, 2016). Answering this question requires identifying the targets of the intervention, the aspects of self-regulation skills that need to be specifically trained, as well as the context in which these trainings have to occur. The work carried out by Diamond & Ling (2016) already makes it possible to orient this research by means of a list of what interventions works and what does not work. However, among these efficient intervention, we know very little about the origin of cognitive benefits, on what neurocognitive mechanism are these improvements based? Thus, above all, it is important to better understand how training programs influence the brain mechanisms of executive functions and their developmental processes, and how variations in the training contexts and targets differently affect these mechanisms.

Evaluations of early interventions and training programs to promote children's self-regulation through executive function stimulation have yield inconsistent results, partly due to the context in which these activities take place (i.e. intervention proposed to typical children, low-socioeconomical status children, or children with low executive level) but also to differences in the type of training considered. Karbach and colleagues (2014) defined three types of training: i) processes-based training which target specific cognitive processes underlying the realization of a cognitive task, ii) strategical training which teach children to think about what and how they have to do to reach a determined goal, and iii) ecological training which immerses the child directly in a context in which he can experience the targeted skills. Overall, it would seem that the social context, inherent in group activities, as well as the imposition of an exercise framework, supports the use of skills involved in behavioural self-regulation such as self-control, empathy, theory of mind and metacognition. These skills are based on the implementation of cognitive control, the ability to adaptively orchestrate the solicitation of executive functions relative to a goal and in relation to the need imposed by the current situation. Thus benefits of intervention targeting executive function could benefit both the efficiency of cognitive processes relying on structural and functional aspects of the brain, as well as the behavior through an enhancement of the potential of self regulatory skills.

Multilevel assessments have already been used to study the extent of the effects of processes-based training. This kind of intervention specifically target executive function processing through task repetition, mainly mobilizing inhibition, working memory or flexibility, the three core executive functions. Previous research highlight the efficiency of

processes-based training to generate improvement at the cognitive level (Bergmann Nutley et al., 2009; Thorell et al., 2009; St Clair-Thompson et al., 2010 ; Kloo and Perner, 2003; Röthlisberger et al., 2011; Dowsett and Livesey, 2000) although mixed results were obtained for inhibition (Rueda et al., 2005; 2012; Thorell et al., 2009). Moreover, they also shown that improvement was associated to changes at the neural level (Pietto et al., 2018; Liu et al., 2015; Espinet et al., 2013; Rueda et al., 2012). These studies seem to indicate that an increased stimulation of executive processes allows an improvement in the efficiency of these processes, enabled by the optimization of the underlying neural networks and their functioning. These benefits have been demonstrated through post-intervention changes in cerebral measures like modification of the brain structure (i.e. increase of white matter thickness in specific brain regions, Park et al., 2015), as well as more mature neural responses (i.e. change in the conflict evoked-response potential N2 in frontal regions: Rueda et al., 2005; Rueda et al., 2012; Pietto et al., 2018) and functional activity (i.e. increase of the effective connectivity between frontal and parietal sites: Astle et al., 2015; Wang, Weng, Yao, Dong, Liu & Chen, 2017). However, studies are struggling to establish a practical interest in such training given the little evidence that shows behavioral improvement in these approaches. In fact, the benefits remain largely specific to the processes involved and within the framework of the training task. Importantly, there is limited evidence that these training activities benefit other child's behaviors and skills that also engage executive functions, like academic learning and socioemotional skills (Melby- Lervag and Hulme 2013; Thorell et al. 2009; Titz and Karbach 2014). One might wonder if the evaluation of executive functioning through its components taken independently is an optimal mirror of behavioral control capacities.

On the other hand, strategical as well as ecological training are prompt to benefit directly the behaviour,. This last category fits into a more realistic approach and might be more effective at obtaining beneficial outcomes in these domains (Diamond and Lee, 2011, Bryck and Fisher, 2012). These trainings do not narrowly focus on executive functions but also address child's social and emotional functioning and academic learning. The training of executive functions is directly embedded within academic or social activities, allowing children to coordinate executive functions with social, and emotional processes or learning processes (i.e. art-based, play-based, or physical-based activities).

For example, the Tools of the Mind early childhood curriculum, sees executive functioning as a central mechanism of child's progress in his or her academic skills and social-emotional skills and has explicitly included executive functioning as core target of its teaching and learning activities. This curriculum is based on the socio-cultural perspective of Vygotsky (1978), which emphasizes the fundamental role of social interactions on child development and learning. Central to this curriculum is the sociodramatic play (pretend play), which consists in small group-based activities where children engage in pretend play. Sociodramatic play is one of the essential preschool activities for children, it requires establishing a play scenario with its different events, selecting and coordinating the play roles of each child, and planning the actions to be executed by the children (Stambak and Sinclair, 1993; Vygotsky, 1967). Pretend play may therefore serve as a vehicle to support and foster the child's self-regulation skills through his/her social interactions with his peers and his teacher (Bodrova and Leong, 1996, 2001, 2007, Vygotsky, 1967, Berk et al., 2006). Furthermore, pretend play offers opportunities for the child to engage his cognitive control across various cognitive, social and emotional domains in order to regulate his own behavior. For example, while playing children hold in memory, information related to the play theme and their own roles. They also use inhibitory control to refrain from acting in ways that are inappropriate with the current play, and mental flexibility to adapt their actions to changes in the play. Pretend play also allows executive functions to operate in the social domain to enable the child's to take his or her turn, take other children's ideas into account, as well as resolve conflict and cooperate (Fisher, 1992). Finally, during the play, children also have to regulate emotions and feelings like excitation, frustration or even anger (Barnett, 1984; Christiano & Russ, 1996; Dansky, 1980; Galyer & Evans, 2001).

Assessments of preschool children's self-regulatory skills during play activities indeed show that children as young as three years old engage various self-regulation skills while playing (Berk et al., 2006 ; Robson, 2010). This engagement is also associated with the quality of pretend play, defined as the complexity of the play theme (definition of the roles, the scenario and its actions), the use of pretense in the play or else the level of symbolization (Bodrova & Leong, 2007). The quality of the play has been associated with both lower-level executive functions (working memory, inhibition and set-shifting) and higher-level executive functions like planning and conflict resolution (Carlson et al., 2014, Vieillevoye and Nader-Grosbois, 2008; Nader-Grosbois and Vieillevoye 2012;, Matthews, 2008; Slot et al., 2017) as well as

emotional self-regulation, (Galyer and Evans, 2001; Gilpin, Brown, & Pierucci, 2015; Lindsey and Colwell, 2003; Slot et al., 2017; Elias and Berk (2002)). Randomized-controlled trials evaluations of the Tools of the Mind curriculum has shown improved performance on lower level executive functions, like working memory, set-shifting and inhibition in both preschool (Diamond et al., 2007; Diamond et al., 2020) and school age children (Blair and Raver, 2014), as well as improved vocabulary and mathematics (Barnett et al., 2008; Diamond et al., 2007, 2020 Blair and Raver, 2014) and better socio-emotional skills with less externalized behavior and better conflict resolution skills (Barnett et al., 2008). It has also been shown that following a one year period of Tools of the Mind curriculum, children were more able to independently maintain a role play relatively to a control group (Diamond et al., 2019). However, it is not possible to dissociate the part of the improvement linked to the pretend-play activities from all the other support activities. In order to particularly investigate the ability of pretend-play to sustain the executive processing underlying self-regulation studies have systematised play activities into a training program. Among them, two studies have shown that regularly engage preschoolers in pretend play activities improved their executive functions (Thibodeau, Gilpin, Brown, & Meyer, 2016; Traverso, Viterbori, & Usai, 2015). In these two studies children played in group and fa... (Nicolas, décrit activités en 2-3 lignes). Improvements in working memory and flexibility (Traverso et al., 2015) (Thibodeau et al., 2016) as well as inhibition (Traverso et al., 2015) were observed following the training, with greater effects for children who were highly engaged in the play (Thibodeau et al., 2015). These results show that pretend play might be an effective approach for training preschoolers' executive functions.

In the present study, we assessed whether using only the pretend play activities of the tools of the mind curriculum will lead to the same beneficial effects on cognitive control and socioemotional skills than those obtained with the whole curriculum. This question has important educational implications because self-regulation training activities are more easily to implement in classrooms than a whole curriculum because they require limited time and personnel resources and use materials that are available at low cost. We capitalize on previous findings to assess for the first time whether pretend play also affects the brain mechanisms of cognitive control and whether training gains also benefit children's behavioural outcomes through self-regulation and socioemotional competences. We assessed the effect of pretend play on mid-frontal theta neuro-oscillatory activity (MFT), which is considered a neural mechanism of cognitive control in both adults and children (Cavanagh & Frank, 2014; Cohen



& Cavanagh, 2011, Liu, Woltering, & Lewis, 2014, Adam et al., 2020). Neural oscillatory activity within the 4-8 Hz theta frequency range has been proposed to enable the coordination of the neural computations underlying cognitive control (Buzsaki & Draguhn, 2004; Doesburg, Vidal, & Taylor, 2013; Von Stein & Sarnthein, 2000). MFT is generated within the anterior cingulate cortex and reflects both the need for cognitive control as well as the recruitment of cognitive control processes (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999). Importantly, MFT might serve as a general neural mechanism of cognitive control because it is involved in different implementations of cognitive control, for inhibiting a dominant response and for shifting of task set, and at different developmental periods, covering both the preschool and school ages children (Adam et al., 2020). MFT power reflects the engagement of cognitive control (ref) while MFT latency reflects the time to set up oscillatory activity within the theta range in a brain network. MFT latency is sensitive to age with a decrease in this latency between preschool and school ages, suggesting that this MFT activity is set up more rapidly in school age children compared to preschool children (Adam et al., 2020). Furthermore, given that pretend play offers opportunities for the child to coordinate executive functions with socioemotional processes, we also addressed whether pretend play can also benefit child's socioemotional skills as well as behavioral self-regulation in settings other than pretend play. Indeed, no attention has been dedicated to how EF training in socially salient situations, like pretend-play, where cognitive control processes interact with social and affective processes, can benefit the child's socioemotional skills in other daily activities. Answering this question is important to better understand the impact of pretend play on the child's cognitive, social and emotional development and in particular assess whether pretend play is also effective at promoting preschoolers' socioemotional skills.

We implemented, the sociodramatic play activities of the curriculum Tools of the mind in preschool children and evaluated this training using a randomized controlled trials-based approach where preschool children were randomly assigned to a treatment group with pretend play activities or an active control group. Pretend play training consisted in scaffolded and support of the child play by experimenters in order to increase the maturity the child's play, which places higher demands on executive functions. Experimenters' support of the child's play was based on the approach developed by Bodrova and Leong (2007).

We hypothesized that support of pretend play help the child to play at a more mature level which places higher demands on the child's executive functions. This would impact the

cerebral mechanisms underlying the use of EF leading to improve the efficiency of their cognitive control. These benefits could also prove to be profitable at the behavioral level by increasing the potential of self-regulatory skills. Thus, we assessed the effects of pretend play training by investigating three levels of measures: behavioural (self-regulation and socio-emotional adaptation), cognitive (executive functions) and neuronal (MFT power and latency).

## **Material and methods**

### **Schools and Participants**

The study was conducted in two pre-kindergarten schools (selected by the federal education authority) in the city of Montauban in France. These schools were part of the French education priority networks, which provide additional resources for strengthening educational and pedagogical action to French schools districts that face the greatest social difficulties. An oral agreement to participate in the study was obtained from school administrations. The two schools had respectively three and four pre kindergarten classrooms.

Families were informed of the study through a written document sent to them as well as during an information meeting. They accepted the random assignment of their children to the training or the control group and provided written informed consent for children to participate to both the intervention and the evaluation parts of the study. Children gave a verbal consent. A separate consent form for collecting EEG measures in children was provided to families. Only children for whom parents provided their written consent were tested with EEG.

The families' sociodemographics characteristics are described Table XX. However these sociodemographics statistics were calculated from an understaff of parents as only 40% of the families returned the questionnaire completely fulfilled. The median reported family income for both schools was \$25,000–50,000 annually. All the procedures of the study, relative to the implementation of the program (pretend play and control activities) and to its evaluation, were approved by the local ethics committee (N° 2-15038).

72 preschool children ( $M = 60.44$  months,  $SD = 6.63$ , range = 47–71 months, 39 boys and 33 girls) participated in the study. Children pertained to four classrooms (two in each school) that included children aged four to six years old.

To ensure the homogeneity of our control and training groups in terms of cognitive control, non-verbal intelligence and vocabulary skills, we used a pairwise randomisation design where

each child from the training group was paired to a child from the control group based on their standardised pre-test performance on a non verbal IQ test, a cognitive control task and a vocabulary test. This pairwise design was also constrained to ensure similar demographics characteristics (age and sex) between our groups. Finally, to control for potential influence of teacher characteristics and experience on training outcomes, the randomization was conducted in each classroom. Therefore both children of each pair had the same teacher and had sociodemographics characteristics, non-verbal intelligence, cognitive control and vocabulary performances as similar as possible.

All children were assessed at two time points: in the fall, within 6 weeks prior to the start of the intervention (Pre-test), and in the spring, within 6-weeks following the intervention (Post-test). These assessments included a control cognitive task, a receptive vocabulary test a behavioral self-regulation task and a non-verbal intelligence test. Assessments were conducted on two non-consecutive days in a quiet classroom of the school. In one assessment session, the non-verbal intelligence test, the receptive vocabulary test and the behavioural self-regulation task were administered in a counterbalanced order between children. The other session involved the cognitive control task with EEG testing for children for whom a parental consent was given. Each session took less than one hour to complete.

Questionnaires on children's self-regulation and socioaffective skills were collected from parents at both time points.

## Measures

### Vocabulary ability

Receptive vocabulary ability was assessed with the EVIP NAME (Dunn et al., 1993), which is the French version of Peabody Picture Vocabulary Scale. It is adapted to children aged two to six years old and requires the child to access and retrieve words from memory. Children were presented with four pictures and had to point to the picture corresponding to the word spoken by the experimenter. The starting of the testing was adapted to children's age. Raw scores were calculated based on the number of correct responses.

### Non-verbal intelligence (general reasoning, fluid intelligence)

Non-verbal intelligence was assessed using the Raven Colored Progressive Matrices (CPM, Raven, 1998), which is a child-friendly version of the Raven's Matrices. This standardized test is a multiple-choice test that requires children to complete a series of incomplete patterns. Children are presented with an incomplete pattern from which a single

piece is missing. They have to select the missing piece, among six possible ones, that best completes the pattern. Children were presented with three sets of increasing difficulty, each containing 12 patterns. The score was the total number of correct responses and was standardised for age.

#### Behavioral self-regulation

The Head-To-Toes-Task (H3T, Cameron et al., 2009) was used to assess children's behavioral self-regulation. This task involves working memory, inhibition and flexibility (McLelland et al., 2014) and is appropriate for children aged four to eight years old. It requires children to execute an action given by an examiner (i.e. touch your head or touch your toes) and then to switch the rules by acting in the opposite way (touch his/her head when asked to touch his/ her toes). A total of 10 actions are given to the child.

#### Behavioral assessment of executive functions

Behavioral assessment of executive functions was conducted with the French version of the Behavioral Rating Inventory of Executive Functions (Gioia et al., 2014). This questionnaire assesses the behaviour of children and adolescents aged 5 to 18 years in their school and/or family settings. It provides several scores measuring different aspects of executive functioning. We only used the raw scores because some of the children were only four years old and because we directly compared measures between our training and control groups. . Finally, the questionnaire was only provided to the children's parents, this assessment therefore only relates to the child's behavior in the home setting.

#### Socio affective skills

The Socio-affective Profile (Lafrenière et al., 1997) was used to assess children's socioaffective skills. This questionnaire is appropriate for children aged two to six years old and accurately describes child's emotional and behavioural tendencies. It provides scores on the child's social competence, internalizing behaviour, externalizing behaviour and general adjustment external. The parents completed this questionnaire.

#### Sociodemographic information

Parents provided information relative to the family environment (number of children, language spoken at home, physical activity practiced), as well as information about them (level of education, occupation, salary range), and their child (age of entrance at school prematurity, health problems).

### Maturity of pretend play

The maturity of pretend play is positively associated with cognitive and emotional self-regulation (Carlson et al., 2015, Slot et al., 2017). Because more mature play place higher demands on the child's self-regulation skills, the maturity of play can be used as a proxy of the engagement of self-regulation skills in the child's play. Maturity of each child's pretend play was assessed with the use of the Propels grid developed by Bodrova and Leong (2007) which involves five criteria that describe critical aspects of the play (planning of the play, use of language, use of props, complexity of the scenario, complexity of the roles, complexity of the actions and extended time frame). Each of these criteria evolves as the child's play becomes more mature and this progression goes through five stages (see table for a detailed description of each stage in the Propels grid).

We assessed all the criteria, except the extended time frame because this criterion was not adapted to our assessment procedure. Criteria were scored from the five stages grid, which was converted into a five-levels scale. Lower scores corresponded to less mature stages of the play and higher scores to more mature stages of the play. Therefore, each criterion of the child's play was scored between 1 and five. For example, for the plan criterion, if the child did not plan during the play (stage 1), his plan was scored one, and it was scored five if he, planned elaborate themes, complex scenarios and roles. Intermediate scores were given for intermediate stages.

This assessment was done two times, prior (pre-test) and after the intervention (post-test). It was conducted by observing groups of four children playing together during fifteen minutes with no supervision from an adult. Each group was assessed one at a time by the two experimenters who supervised the pretend play activities. The choice of having the same experimenters who run and assessed the play activities was justified by the need of very good expertise in playing pretend play with children to accurately assess the different criteria of the play. However, to limit the potential bias of having non-blind experimenters, the following precautions were taken. First, to improve accuracy of measurements, each child's play was assessed independently by the two experimenters. The child's final scores were the mean of the two examiners' scores. Second, groups of children were created by mixing children from the control and the training groups. Therefore, experimenters did not know to which group had been assigned most of children (they only knew the group of the children they themselves trained). Finally, the play sessions were recorded to allow further assessments when needed.

## Cognitive control task

Cognitive control was assessed with the Hearts & flowers task (Davidson et al., 2006; Diamond, Barnett, Thomas, & Munro, 2007). We only used the mixed block of this task as it engages all cognitive control components, working memory, set shifting, and motor inhibition and is appropriate for children from the age of four.

This task allows assessing cognitive control in different conditions of interference. The interference could either occur at the response level (between two motor responses) or at the task-set level (interference between two task-sets). There were four interference conditions: i) the null interference condition (cC), in which there was no interference; ii) the response interference condition (iI) where children had to inhibit the dominant motor response and respond on the other side of the stimulus. iii) In the task-set interference condition (iC), children had to inhibit the previous task-set and switch to the current one. iv) finally, in the task and response interference condition (cI), children had to both switch of task-set and inhibit a dominant motor response.

The experimental paradigm is presented in the figure 1. The task was presented on a Mac Laptop (13.3-in, screen refresh rate: 60Hz) using the OpenSesame software (Mathôt, Schreij, & Theeuwes, 2011) to display stimuli and record responses. Responses were collected via a button box with two buttons (for left and right index fingers) the pressure of which was adapted to the children's fingers' strength. Participants were positioned approximately 0.40 m from the screen. Children were presented with a central black fixation cross (70 mm diameter, 1°) with either a red heart or a red flower (30 mm diameter, 4.3°) appearing on the left or the right (20 mm, 2.87°) of the fixation cross. Children were instructed to respond as fast as possible when a stimulus appeared. The stimulus remained on the screen until a response was made or up to a maximal time duration of 2500ms. Once the children gave a response, they received a visuo-auditory feedback with a low-pitched tone of 500 ms accompanied by a surprised face for an incorrect response or an absence of response, and a high-pitched tone of 500ms accompanied by a happy face for a correct response.

The task consisted of 8 blocks of 16 trials each (132 trials in total) with compatible (“press the key on the same side as the heart”) and incompatible (“press the key on the side opposite the flower”) intermixed trials (see Adam et al. 2020 for more detail information on the testing procedure).

*Figure 1: Experimental paradigm of the Heart & Flower task with illustration of an incompatible current trial that follow a previous incompatible trial. This trial requires overpassing the pre-potent response of the current trial and to alternate task-set compared with the previous trial*

## EEG procedure

(suffisant???)°

EEG measures were also collected from a subsample of 52 children (mean, age,). EEG testing, and material were first presented to children, and then the child and the experimenter installed the EEG cap together on a teddy bear. When the child was comfortable with the material, the experimenter installed it while the child watched a cartoon. After completion of the first session, children were assigned to either the experimental (to-be-trained) or the active control (untrained) group. The sample was composed of 69 children, two children were not included because they were reported with developmental disorders and one child moved just after the pre-training phase. Considering the sample size the assignment was not randomized but was made with a pairing procedure so groups would be equilibrated in terms of IQ, vocabulary comprehension and performance at the HF task.

The EEG recording and processing parameters were the same as those used by Adam et al., (in review). A Biosemi Active-Two amplifier system with 64-channels positioned according to the 10-20 International system was used. Continuous data was epoched from -1500 to 3000 ms relatively to the stimulus onset. Epochs containing ocular and motor artifacts during the baseline or stimulus presentation time were rejected. Thereafter, independent component analysis (ICA) was performed (Delorme and Makeig, 2004), and components that did not account for the brain activity (eye-blinks, horizontal eye-movements or muscle activity) were subtracted from the data (Chaumon, Bishop, and Busch, 2015). Only correct response trials were included in the analysis, errors, post-errors, anticipatory responses as well as warm-up trials (first trial of each block) were removed from the data. After the preprocessing steps, analyses were done on the averaged EEG measures computed on a total of 1695 cC , 1932 cI, 1883 cI and 1680 iI trials, with an average of 82 trials per child and a total of 2623 cC, 2947 cI, 2865 cI and 2660 iI trials with an average of 92 trials per child. Children who had been excluded from the behavioral analyses were also excluded from the EEG analyses. We isolated mid-frontal theta (MFT) activity using optimal spatial filters - a weighted

combination of all channels - designed to maximize power in the theta band (Cohen, 2017; Gulbinaite et al., 2017).

Conflict-related brain activity was extracted during cognitive control processing (stimulus-locked analysis) time windows (Cavanagh et al., 2012; Gulbinaite et al., 2014). To extract individual theta measures we first identified the individual theta power peak in the condition-averaged data and determined a subject specific window both in frequency ( $\pm 1\text{Hz}$ ) and time ( $\pm 150\text{ms}$ ) to compute the average of theta power. A theta measure was then extracted for each trial by averaging the raw power observed during the subject specific time and frequency window. Finally, the single-trial power values were averaged across trials for each condition separately, and normalized relative to the condition-average baseline period (-400 -100 ms) using a decibel (dB) transform at each frequency:

$$\text{dB power} = 10 \times \log_{10}[\text{power}/\text{baseline}]$$

Conversion to a dB scale ensures that data across all frequencies, time points, electrodes, conditions, and subjects were in the same scale and thus were comparable.

## Intervention

Children of the training (N=36) and the control groups (N=33???) Ca fait 69 pas 72) were grouped into small groups of four children each, mixing boys and girls, children from different classrooms and of different ages. The training and control activities lasted forty-five minutes and were held two times a week, on the same days and at the same time (in the morning).

Both training and control activities were carried out in quiet rooms of the school. Training activities were conducted by two experimenters, Chloe Farrer and Nicolas Adam, the control activities were conducted by Students in Psychology (master level).

The intervention lasted 10 weeks with a total duration of 15 hours (with two sessions of 45 minutes every week). The intensity and the duration of the training were similar to those used in previous cognitive training studies using either the pretend play approach (Traverso et al., 2015, Thibodeau et al., 2016) or other approaches (Tominey et al., 2011).

## Training activities

Training activities were developed by taking into account critical elements of pretend play: i) the scenario content (Bodrova & Leong, 2012; Umek & Musek, 1998; Umek, Musek & Pecjak, 1999; Weisberg et al., 2015; Thibodeau et al., 2016), ii) emotional content (Dias et al., 2016); iii) props and accessories (Bodrova, 2008 ; Bodrova & Leong, 2006); iv) language and



verbalization (Landry, Pagé & Bouchard, 2013; Chantal et al., 2016) and v) scaffolding and role of the experimenter (Bodrova & Leong, 2012; Karpov, 2005; Pelligrini, Dupuis & Smith, 2007; Kraft & Berk, 1998; Deneault et al., 2014).

The content and the evolution of training activities also took into account key success factors of training that explain beneficial training outcomes (Diamond and Ling, 2016). They concerned the child's motivation (the play theme was renewed every week to maintain the child's interest in the play), the intensity of the training (there were two weekly sessions of 45 minutes each to give children enough time to play), and the increase in the complexity of the training in order for executive functions and self-regulations skills to be continually challenged (scaffolded support of the play allowed critical play criteria to evolve towards more mature stages over the intervention). Finally, the scaffolding of the play was individualized for each child, based on the evaluation of his/her play maturity prior the training.

The content and the scaffolding of pretend play activities were based on the Tools of the Mind curriculum

Each training session was composed of three steps.

i) The briefing (10 minutes). Each session started with the presentation of the play theme to children (e.g. restaurant or market theme) by reading a story, posting pictures on the wall or using videos. This allowed children to all have the same information. The experimenter then described the play area, with its different parts (the area being organised by the experimenters to be adapted to the play theme (delimitation of different zones of the play area, selection of appropriate accessories, furniture....). The experimenter then asked each child to choose his or her role (character) and to describe the actions (individual and social actions) that he or she would perform. Once each child's role and actions were defined, the play started. To help children remember the story, their roles and their actions, we used a storyboard with pictograms that represented each character and their associated actions, as well as additional pictograms representing other characters and actions (to help the child develop their play). In addition, the storyboard also displayed a play map representing the different locations associated with the theme.

ii) Pretend-playing session (25 minutes). Children were encouraged to execute the actions corresponding to their role in the play area. The experimenter supervised the play and helped the children, when needed, to remember the scenario, his role and the corresponding actions, or to resolve a conflict with another child. He also helped children to make the play evolve (with new script elements, new roles and new actions). For this, the experimenter could

temporarily take on a role and enter the play. To maintain children's motivation, the play themes were renewed every week.

Scaffolding pretend play is important to help children have a more mature play that engages more self-regulation skills. For this reason, the experimenters helped children to play at an increasingly higher stage level over the training, progressing on each criterion. Scaffolding strategies to support and develop the play were taken from Bodrova and Leong.

For example, over the training period, scenarios evolved from familiar and realistic themes (e.g; restaurant or medical themes) towards scenarios involving more fantastic and imaginary themes. See Thibodeau for the importance of fantastical oriented play on development. Concerning accessories, children were mostly provided at the beginning of the training with concrete toys and figurative accessories appropriate with the theme play (i.e. medical equipment for the doctor's theme, plastic fruits for the market scenario...) whereas more symbolic accessories (plastic boxes, pieces of fabric, plastic tubes) were provided to them throughout the training period. This evolution also applied to the play area, with a few well defined areas with appropriate furniture at the beginning (e.g. for the restaurant theme, we had two delimited areas, one for the kitchen, the other one for the restaurant room) to less well defined areas that could be reorganised by children to fulfil several functions (e.g an island or a castle).

iii) The debriefing (10 minutes). Children were gathered in front of the experimenter. They were encouraged to recall the play theme, the roles, and the actions they executed. They also discussed other alternatives that could have occurred in order to help children think about the forthcoming play session.

#### Control activities

Control activities consisted in art craft activities (i.e, drawing, modelling clay or cutting-gluing works) and were supervised by a student in Psychology (licence level). These activities also evolved over the intervention with more activities of XXX

Children completed on average 16 sessions (range 9-18) for the training group and 15.4 sessions (range 8-18) for the control group.

#### Experimental design

Two children (one in each group) were removed from the sample because of repeated and lengthy absences. Fifteen subjects were also removed from the analyses because of very poor performance on task (error rate > 45%; N=8), or technical problems (N=7). The final sample included 60 children (N=31 for training group and N=29 for control group).

The intervention was evaluated using a pairwise randomized controlled trial. Within each class, and EEG category children were grouped into pairs. We paired children according to their cognitive control, vocabulary and fluid intelligence (using the normalized EVIP, CPM and dots scores). Pairs were formed by minimizing the total sum of a Mahalanobis distance between children from the same class and the same EEG category. Optimal pairs were computed using a non directed search algorithm sampling randomly pairs within strata and looking for the minimum total distance. Randomization to the treatment or control condition was conducted at the child level. Within each pair, we selected at random (using a pseudo-RNG algorithm) one children to be in the treatment group and the other to be in the control group.

Analysis of the experimental results was conducted using a linear model with both pair and children fixed effects, ensuring that all comparisons are pre-post within pair, and a dummy for group factor. For some variables, the pre-post comparison is much noisier than the post variable, because of large amounts of measurement error. We chose to report results from within pair comparison of post outcomes in that case.

We chose a pairwise design in order to increase the precision of our experiment as much as possible. However, in a pairwise design, any attrition dramatically affects the sample size because for each child lost from the initial sample the paired children is also excluded. Eventually, the final analysis includes 26 pairs of 52 children. Analyses were also conducted without the pair factor on the whole participants sample. Results did not differ from the pairwise analyses and are available upon request to the first author.

Finally, additional analyses were conducted without the pair factor on the whole participants sample. Results did not differ from the pairwise analyses and are available upon request to the first author. We also assessed whether the training effect on cognitive (accuracy and reaction times) and neural measures (MFT power and latency) of cognitive control differed according to the type interference to resolve by adding an interference condition (iI, iC, cI, cC) as a fixed effect in the model. When needed, planned contrast analyses were further conducted to compare neural and cognitive measures between groups. All analyses were run with R software (R Core Team, 2014).

$R^2$ , t or z-values and their associated p-values are reported, as well as the number of subjects and pairs included in the analyses. We also reported effect sizes using the Cohen's d (in units of standard deviation), with its associated standard error and 95% confidence

interval. A Large effect is for an effect around .8 of a standard deviation, a medium effect for an effect around .5 of a standard deviation, and small and very small effects for effects around .2 and below .2 of a standard deviation).

#### Power analysis and pre-registration

Minimum detectable effect size was calculated for the main outcome (mean accuracy for cognitive control). Standard error of the training effect estimator including pair fixed effect is of 0.122, which implies a minimum detectable effect size (for one-sided t-test of size 5% and power 80%) of 0.303.

The analysis was pre-registered before seeing the data and follows a pre-analysis plan that can be found here: <https://doi.org/10.1257/rct.2787-2.0>

## Results

### Baseline differences

Training and control groups were formed to ensure similar performance for cognitive control measures (mean accuracy across all conditions), vocabulary and fluid intelligence prior the training. We also checked for potential differences between control and experimental group on other outcomes variables were present prior the training. Both groups were well-matched regarding MFT power, MFT peak latency, maturity of play, behavioral self-regulation scores and socioaffective skills score.

Scale	Outcome	Mean <sub>ctrl</sub>	SD <sub>ctrl</sub>	Mean <sub>exp</sub>	SD <sub>exp</sub>	t_val	p_val	N	Rsq
Behavior:	H3T	16,38	3,77	15,27	4,22	-1,067	0,291	59	0,020
	BRIEFBRI	42,20	6,55	47,68	10,84	1,748	0,089	37	0,080
	PSAEGAS	34,79	3,93	35,63	3,38	0,629	0,534	30	0,014
	PGPlanning	1,42	0,50	1,50	0,51	0,547	0,587	52	0,006
	PGRole	2,04	1,00	2,08	0,98	0,140	0,889	52	0,000
	PGPropels	2,69	1,01	2,58	1,14	-0,387	0,701	52	0,003
	PGLanguage	2,27	1,08	2,00	0,85	-1,000	0,322	52	0,020
	PGScenario	2,38	0,98	2,00	0,94	-1,443	0,155	52	0,040
Cognitiv	EVIP	105,48	23,03	105,23	21,69	-0,045	0,965	60	0,000
	CPM	20,38	6,14	19,58	6,27	-0,498	0,620	60	0,004
	RT	1259,00	154,72	1254,31	162,03	-0,110	0,913	55	0,000
	c <sub>ctrl</sub>	1160,35	165,91	1126,41	195,77	-0,692	0,492	55	0,009
	c <sub>exp</sub>	1304,41	230,79	1320,48	231,62	0,258	0,798	55	0,001
	i <sub>ctrl</sub>	1310,54	207,62	1314,57	265,84	0,063	0,950	55	0,000
	i <sub>exp</sub>	1234,26	247,49	1239,11	235,30	0,074	0,941	55	0,000
	Accuracy	87,38	9,31	85,27	10,38	-0,791	0,432	55	0,012
	c <sub>ctrl</sub>	87,44	11,88	84,86	14,71	-0,713	0,479	55	0,010
	c <sub>exp</sub>	83,27	14,19	78,81	13,90	-1,179	0,244	55	0,026
	i <sub>ctrl</sub>	80,33	15,55	77,99	14,79	-0,571	0,570	55	0,006
i <sub>exp</sub>	88,31	13,09	83,38	13,84	-1,357	0,180	55	0,034	
Neuron:	MFTPower	2,23	0,65	2,42	1,16	0,622	0,538	38	0,011
	c <sub>ctrl</sub>	2,25	0,72	1,95	1,25	-0,895	0,377	38	0,022
	c <sub>exp</sub>	2,43	1,30	3,05	1,60	1,289	0,206	38	0,044
	i <sub>ctrl</sub>	2,54	0,98	2,47	1,66	-0,137	0,892	38	0,001
	i <sub>exp</sub>	1,69	1,08	2,20	1,09	1,459	0,153	38	0,056
	MFTLatency	732,99	413,40	850,63	432,24	0,855	0,398	38	0,020

### Effect of training

Scale	Outcome	Effect	SeEffect	t_val	p_val	N	lowCI	highCI	Rsq
Behavior	H3T	-0,18	0,26	-0,70	0,490	26	-0,70	0,33	0,000
	BRIEFBRI	0,35	0,49	0,72	0,497	7	-0,60	1,31	0,000
	PSAASA	-0,57	0,23	-2,53	0,040	8	-1,02	-0,13	0,000
	PGPlanning	0,85	0,27	3,11	0,006	20	0,31	1,39	0,000
	PGRole	0,78	0,31	2,49	0,022	20	0,17	1,40	0,000
	PGPropels	0,76	0,30	2,57	0,019	20	0,18	1,34	0,000
	PGLanguage	1,03	0,26	3,94	0,001	20	0,52	1,55	0,000
	PGScenario	0,93	0,29	3,25	0,004	20	0,37	1,49	0,000
Cognitiv	EVIP	-0,06	0,25	-0,23	0,820	26	-0,55	0,44	0,000
	CPM	0,35	0,25	1,41	0,172	26	-0,14	0,83	0,000
	RT	-0,22	0,22	-1,01	0,320	26	-0,66	0,21	0,000
	cTrials	-0,19	0,22	-0,88	0,389	26	-0,62	0,24	0,000
	clTrials	-0,10	0,26	-0,37	0,712	26	-0,61	0,42	0,000
	iTrials	-0,12	0,23	-0,54	0,596	26	-0,57	0,32	0,000
	ilTrials	-0,41	0,25	-1,61	0,120	26	-0,91	0,09	0,000
	Accuracy	0,00	0,28	0,02	0,987	26	-0,55	0,56	0,000
	cTrials	-0,05	0,32	-0,15	0,886	26	-0,68	0,59	0,000
	clTrials	-0,23	0,25	-0,91	0,370	26	-0,73	0,27	0,000
	iTrials	-0,02	0,28	-0,07	0,942	26	-0,57	0,53	0,000
	ilTrials	-0,04	0,30	-0,13	0,898	26	-0,62	0,55	0,000
Neuron:	MFTPower	-0,21	0,22	-0,94	0,371	10	-0,63	0,22	0,000
	cTrials	-0,02	0,20	-0,09	0,929	14	-0,42	0,38	0,000
	clTrials	-0,19	0,31	-0,60	0,557	14	-0,80	0,43	0,000
	iTrials	-0,26	0,38	-0,70	0,496	14	-1,00	0,47	0,000
	ilTrials	-0,39	0,34	-1,14	0,275	14	-1,06	0,28	0,000
	MFTlatency	-0,01	0,46	-0,02	0,985	10	-0,90	0,88	0,000

Table of training results with Cohen's D as the outcomes effect, standard error of the effect, t-value, p-value, Number of pairs included in the analyse and low and high 95% confidence interval. For convenience significant p-value were colored in red. (H3T : Head to toes Task; BRI : Behavioral regulation Index; GAS : General Adaptation Score ; RT : Response Time; MFT : Mid Frontal Theta)

#### Behavioural measurements

- Maturity of play

An effect of training was observed on the five criterias of the Propels grid (PG) with higher scores for children of the training group compared to the control group as indicated by a positive effect for each score (planning:  $t(20) = 3.11$ ,  $p < .01$ ;  $d = 0.85$  ; role :  $t(20) = 2.49$ ,  $p < .05$ ;  $d = 0.78$  ; propels :  $t(20) = 2.57$ ,  $p < .01$ ;  $d = 0.76$  ; language :  $t(20) = 3.94$ ,  $p < .01$ ;  $d = 1.03$  ; scenario :  $t(20) = 3.25$ ,  $p < .01$ ;  $d = 0.93$ ). These findings indicate that children from the training played at a more mature level and benefited from the scaffolding support of the experimenters. The effect sizes were found to exceed, or to be close to exceed, the Cohen's (1988) convention for a large effect ( $d = .80$ ).

- Behavioral self regulation and socioemotional skills

Figures: d cohen

D measures?

Why select only these brief subscores?

We also examined parents' reports of children's behaviour and emotional reactions using i) the Behavioral Regulation Index (BRI) of the BRIEF questionnaire that represents the child's ability to demonstrate cognitive flexibility and to modulate their emotions and behavior through appropriate inhibitory control; and ii) the General Adaptation Score (GAS) of the socioaffective profile questionnaire (PSA) that is a global measure reflecting the child's relational skills with his peers, with adults as well as his ability to express his emotions. For the BRIEF, no training effects were observed on the BRI. For the PSA, an increase of the GAS was found for the control group only ( $t(8) = -2.53$ ,  $p < .05$ ;  $d = -0.57$ ). However, because of low sample size, bad completion of the questionnaires and of non-random attrition, a high level of attrition was observed for these outcomes (60%) resulting in only few pairs of children included in the analyses ( $N = 7$  for the BRIEF, and  $N = 8$  for the PSA). Therefore, the results of the questionnaires will not be considered in the interpretation of the results.

Finally, motor self-regulation assessed with the H3T did not improve in children from training group compared to the control group. These results indicate that pretend play training did not benefit the child's socioemotional skills and behavioral self-regulation in his home setting.

Cognitive measurements

- Cognitive control

Measures of cognitive control did not improve in the training group compared to the active control group. Mean accuracy and response times did not statistically differ between groups.

We also assessed whether training effect on cognitive control differed according to the type of interference to resolve. Previous research has indeed shown that greater training benefits were observed for the most challenging task conditions (McLelland, Diamond), which involve higher cognitive control demands. The most difficult conditions for pre-

schoolers were the ones involving a conflict at the task-set level (Davidson et al., 2006, Adam et al., 2020). However, even for these conditions, children from the training group did not perform better. These results indicate that children playing pretend play were not better able to cope with cognitive interference.

- Fluid intelligence and vocabulary

We examined standardized laboratory assessments of children's nonverbal IQ and vocabulary. No effects were observed on these measures, showing that children's nonverbal IQ and vocabulary did not benefit from pretend play training.

#### Brain measurements

- Mid frontal theta power and latency

We examined whether pretend play training improved brain functions involved in cognitive control. We observed no effect of the training on mid frontal theta power nor on mid frontal theta peak latency. Assessing the effect of the training by taking into account the interference condition did not reveal any significant interaction between training and interference factors. These results indicate that pretend play training, did not impact the neural activity of mid frontal brain areas supporting cognitive control regardless of the type of interference to be resolved



## Discussion

The Tools of the Mind early childhood curriculum includes self-regulation as core target of its teaching and learning activities and has shown improvement in child's executive functions, and socioemotional skills. It is however unknown whether the same beneficial outcomes could be obtained with only a subset of key activities focusing on self-regulation. This question has important educational implications because EF training relying on a limited set of ecological activities are easier to implement than a whole curriculum. We have assessed the pretend play activities of the curriculum Tools of the Mind which are considered as key activities for promoting the development of child's self regulation. These activities are easily implementable in classrooms because they use cheap materials that are yet available in classes and require limited time and personnel resources.

Benefits of pretend play on self-regulated skills and executive functions, has been extensively theorized but empirical evidence is still scarce. Only two studies have shown that regularly engaging preschool children in pretend play benefited executive processing, notably inhibition and working memory (Thibodeau et al, 2016 ; Traverso et al., 2015), although the evaluation of Traverso did not involve an active control group. The aim of the present study was to further investigate whether scaffolding preschool children during pretend play is an efficient training approach to promote their cognitive control abilities.. We seek to understand whether pretend play impacts the functioning and the development of cognitive control brain networks in preschoolers. Another goal of the present study was to assess whether pretend play can benefit child's socioemotional functioning during his/her daily activities. Effects of the training were assessed by comparing performance of the training group to that of an active control group. To do so, we assessed the effect of our training on brain, cognitive and behavioral analyses were conducted i) at the neural level: on the midfrontal theta neurooscillation underlying cognitive control implementation, ii) at the cognitive level: on the efficiency of processes involved during cognitive control task, and iii) at the behavioural level: through measures of self regulation in the child's daily activities.

Providing support to children's pretend play helped children, improving the maturity of their play. The training was indeed effective at improving the children's autonomy in the play as well as the richness and complexity of the play. Beneficial effects were observed on several criterion of the play maturity, like the richness of the scenario, with more elaborated and complex situations, mixing realistic and fantasy play elements, the complexity of the roles,

with children playing different roles associated with a same scenario, the plan of the play, with more elaborated planning prior the play, and the use of language for describing the scenarios, the roles and the actions during the play. Playing at a higher maturity level places higher demands on the child's executive functions and is associated with increased executive functions performance (Barnett et al., 2008; Slot, ..). However, improvement in the maturity of play did not benefit children's cognitive control nor did it affect its brain mechanisms. Comparing the effects sizes associated with pretend play training with those obtained with the whole Tools of the Mind, we showed that using only a subset of activities, compared to implementing the whole curriculum, resulted in a gain loss on cognitive control estimated at xx (Sylvain).

These findings cannot be interpreted as the evidence of an absence of effect as there may be low to very low effects of pretend play training on cognitive control, but detecting these effects will require testing pretend play with a sample of XX children (see sylvain estimation).

Cognitive control was assessed with tasks requiring resolving a conflict occurring at the response level (inhibiting a predominant motor response) and/or at the task –set level (shifting between two tasks-sets) but no beneficial effects of the training were observed for inhibition or set-shifting. Yet, both inhibition and flexibility performance can improve with repeated and regular cognitive training activities that specifically target these executive functions. Enhanced performance of cognitive flexibility was observed for prekindergarten children (Kloo and Perner, 2003; Röthlisberger et al., 2011) and training inhibitory control benefited the inhibitory skills of kindergarten children (Röthlisberger et al., 2011) as well as preschool children with poor inhibitory control (Dowsett and Livesey, 2000), although other studies failed to find an effect of inhibition training in typically developing children (Rueda et al., 2005, 2012; Thorell et al., 2009). Other studies have reported positive intervention effects in task conditions that place the highest demands on cognitive control (Diamond et al., 2007). One explanation is that training would mostly impact the brain networks supporting cognitive control that are less mature and develop later, perhaps because of a higher- experience dependent- plasticity of those networks, which makes them more influential by environmental stimulations. However, we did not observe an effect of the training in the conditions that were the more challenging for preschool children, that required to shift from one task set to another (Davidson et al., 2006; Crone et al., 2006).

Training activities that specifically focus on cognitive control processes can impact the brain mechanisms supporting cognitive control as early as the preschool ages (Chang et al., 2013; Rueda et al., 2005; Rueda et al., 2012; Pozuelos et al., 2018). Training-related effects were observed on cerebral markers of cognitive control in preschoolers like the event-related brain component N2 (Bruchmann et al., 2010; Kopp et al., 1996), Training induced a decrease in the amplitude of the N2 during the resolution of a conflict (Rueda et al., 2005, 2012; Espinet et al., 2013), with brain activation patterns resembling those observed in older children (Rueda et al., 2005), suggesting that the training might have boost the development of brain networks supporting cognitive control (Jolles and Jonides, ) In the present study, we assessed for the first time whether a more ecologically realistic approach of executive training using pretend play would impact the brain mechanisms of cognitive control and in particular whether the training would boost the development of cognitive control brain networks. The preschool years are indeed a developmental period where the plasticity of these brain networks is high and more likely to be shaped by environmental influences (refs). The various situations of scaffolding pretend play provide the child with appropriate experiences for exercising his/her cognitive control that might potentially foster the development of its brain networks. We assessed mid-frontal theta (MFT) oscillations that support the implementation of cognitive control for resolving different types of conflict (at the motor response level or the task-set level) (Cavanagh et al., 2012; Cavanagh et al., 2015; Braver & Ruge, 2006; Braver et al., 2007, Adam et al., 2020) and at distinct developmental periods covering both the preschool and school ages (Adam et al., 2020). MFT power reflects the level of cognitive control engagement, with greater power associated with greater cognitive control demands (Cavanagh & Shackman, 2015; Hanslmayr et al., 2008; Wascher et al., 2014). Latency of MFT decreases between the preschool and school ages, suggesting that the oscillatory activity of networks in the theta range sets up more quickly in school children (Adam et al., 2020). However, pretend play training did not have any effect on mid-frontal theta power, nor on mid-frontal theta latency, suggesting that the training did not have any effect on the functioning of brain network supporting cognitive control, nor on the development of this network.

Two factors can be proposed for explaining differences in the effects on cognitive control between pretend play training and Tool of the Mind curriculum. First, these two approaches differ in the intensity and the duration of training, which are two important success factors of executive training (Diamond and Lin, 2016). A long duration and a high intensity of training

are indeed necessary for sufficient and regular activation of brain networks supporting executive processes to improve cognitive control performance (Diamond et al., 2016; Jaeggi et al., 2008). This might even be more crucial for ecologically realistic training where cognitive control is engaged within various cognitive, social and emotional domains, therefore recruiting more brain networks than those activated by cognitive training that targets more specific cognitive processes.

In the curriculum Tools of the Mind, the support and the training of cognitive control were interwoven in pretend play activities as well as in other various academic and playgroup activities through each school day (Bodrova and Leong, 2007). This provides the child with various daily opportunities to exercise those regulatory functions across cognitive, social and emotional domains. The training activities of the present study were adapted from the pretend play activities of Tools of the Mind, but without all these additional daily activities that also put a strong emphasis on self-regulation. Therefore, the duration and intensity of our pretend play training may not have been long enough to allow intense and sustained activation of cognitive control brain networks.

Benefits of a self-regulation scaffolding, like those allowed by the Tools of the Mind curriculum, could also rely on other benefits such as metacognitive competencies improvement. Indeed, through selected activities, children are encouraged to monitor and assess their own behaviour. Moreover, some strategies are taught to them such as private speech, reflexive posture or breathing habits, strategies that rely on control skills (Berk et al., 2006; Elias & Berk, 2002).

Indeed, through activities that learn to children using his/her self-regulatory competencies, such programs allow the children to develop strategies and to automatize the implementation of cognitive control in a wide range of situations requiring self-regulation. However, to be effective, these programs have an intense training framework allowing such learning. The diversity of activities could also promote the realization of an increased need for cognitive control in daily activities and so this improvement could be also beneficial during cognitive control task realization.

The content of pretend play, fantastic or realistic content, might also explain differences in the effect of the training as these two types of content place different demands on cognitive control. Thibodeau and colleagues (2015) have indeed proposed that the fantastical dimension of pretend play is necessary to generate benefits like enhanced working memory and attention

shift performance. Compared to realistic pretend play, fantastical play appeals more to children's imagination and requires alternating between the imaginary scenario created by the children and the real space of the play, further engaging and challenging executive functions like working memory and flexibility (Thibodeau et al., 2016). However, their conclusion draws upon a comparison between fantastical pretend play and playful activities (i.e. ball games, coloring). It is, therefore, not possible to differentiate the effects of pretend play per se from that of fantastical pretend play. In the present study, the content of the pretend play activities varied incrementally over the training course with more daily realistic scenarios at the beginning of the training and scenarios more oriented towards fantastical play at the end of the intervention. However, we cannot assess whether the content of pretend play had any effect on cognitive control, as our pre-post training design did not allow us to differentiate the effects respectively associated with realistic and fantastical pretend play. Effects of the pretend play content on cognitive control will have to be more clearly investigated in future studies.

Another goal of the present study was to assess whether pretend play training benefit child's socioemotional functioning in his/her daily activities. Pretend play indeed provides the child with appropriate experiences for exercising his/her cognitive control across social and emotional domains. In our training activities, cognitive control was indeed engaged during social interactions as well as during situations that require regulating emotions. For example, children have to take turn, refrain from acting impulsively to let another child achieve an action, or deal with their frustration or excitation. Regular engagement of cognitive control across cognitive, social and emotional domains has been proposed to explain the transfer effects of executive functions training on socio-emotional skills (Diamond and Lee, 2011, Moreau & Conway, 2014). Furthermore evaluations of the Tools of the Mind curriculum also showed beneficial effects on the child's socioemotional skills, with a reduction of externalised behaviour and better conflict resolution skills (Barnett et al., 2008). However, we did not observe any effects of the training on children's socioemotional skills, as assessed by the parents during the child's daily activities. Compared to pretend play training, the curriculum Tools of the Mind involves additional educational practices and activities where teachers supported children's engagement of cognitive control in social context (Bodrova and Leong, 2007)). These activities might have provided children with additional opportunities to exercise their cognitive control in many situations of social interactions. Therefore, EF training in socially salient situations, like pretend-play, did not benefit the child's

socioemotional skills in his daily activities. The absence of a training-related effect on the child socioemotional skills could also be explained by the active control activities of the control group. These control activities were conducted in the same conditions than the training activities with small groups of children doing some manual activities (i.e. colouring, modelling clay, ...). The content of the control intervention was defined in order to get closer to daily school activities. However, these activities are also the support of pre-academic skills learning (i.e. self-control, listening, problem solving) and de facto have the potential to generate some developmental improvement (Howard et al., 2020). **Greater general adaptation score for the socio-emotional profile questionnaire was observed in control group compared to the training group after the training.** Due to the small sample size considered in this analysis, we do not consider this result, however, given the nature of the control task, **it could therefore be the case that these activities might have had some beneficial effects on some aspects of the child's socioemotional functioning.**

However, l'absence d'effets significatifs sur f et composites peut aussi s'expliquer par une évaluation trop rapide après l'entraînement, des effets peuvent en effet apparaître sur le plus long terme (cf notes Perry et email de Nicolas); longer term effects should be assessed

## **Conclusion**

This study evaluated the effects of pretend play training on child's cognitive control and socioemotional skills. Even though the training well improved the maturity of play, reflecting greater child's autonomy and self-regulation in the context of the play, this training did not improve cognitive control and its brain mechanisms, nor did it affect child's socioemotional functioning in his daily activities. Further evaluations of pretend play training on cognitive control might take into account the effects of factors like the content of pretend play, the intensity and duration of play sessions as well as the type of control activities

## **Conflict of interest**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## **Authors contributions**

NA, CF and AB designed the experiment and the training program. NA and CF carried out the data collection and conducted the training in schools for the experimental groups. RG shared her expertise on EEG data processing and analysis and co-wrote with NA the EEG analysis code. NA and SCF analysed the data. NA, CF, AB participated in the interpretation of the results and NA and CF drafted the manuscript. . All authors approved the final version of the manuscript

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## **10.** Tables

Demographic measure	Experimental group				Control group			
	N	Mean	SD	Range	N	Mean	SD	Range
Age (months)	31	60,5	6,4	48,2 - 70,9	29	62,6	6,1	52,2 - 71,4
Household monthly salary (€)	24	2126,1	884,3	800 - 3000	19	2426,3	1228,7	800 - 5000
Birth weight (kg)	19	3,3	0,6	2,5 - 4,5	13	3,1	0,9	0,785 - 3,9
Daily sleep time (h)	21	10,4	0,6	9,5 - 11,5	15	10,2	0,9	7,5 - 11,25
Weekly screen time consume (h)	21	1,0	0,3	1 - 21	14	1,07	0,9	1 - 28
Age of entrance at kindergarten (months)	23	35,5	4,5	30 - 48	20	39,7	8,8	30 - 66
Intervention attendance (h)	31	12,2	1,3	7,5 - 13,5	29	11,5	1,8	6 - 13,5
Gender	16 boys - 15 girls				15 boys - 14 girls			
Grade composition	16 MSM - 15 GMS				10 MSM - 19 GMS			
<b>Cognitive measure</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Range</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Range</b>
Non verbal Intelligence	31	19,6	6,3	8 - 30	29	20,4	6,1	10 - 29
Language comprehension	31	105,2	21,7	67 - 160	29	105,5	23	62 - 147
Behavioral selfregulation	30	15,3	4,2	4 - 20	29	16,4	3,8	9 - 20
	<b>N</b>	<b>Less than Bachelor</b>	<b>Bachelor</b>	<b>More than Bachelor</b>	<b>N</b>	<b>Less than Bachelor</b>	<b>Bachelor</b>	<b>More than Bachelor</b>
Parents Education (mother)	23	8	7	8	18	7	6	5
Parents Education (father)	22	4	5	13	16	2	5	9
	<b>N</b>	<b>Below poverty line</b>	<b>Below 30% of average</b>	<b>Above median</b>	<b>N</b>	<b>Below poverty line</b>	<b>Below 30% of average</b>	<b>Above median</b>
Household incomes level	24	12	12	0	20	10	1	2
	<b>N</b>	<b>Yes</b>	<b>No</b>		<b>N</b>	<b>Yes</b>	<b>No</b>	
Hobbies Sport practice	24	5	19		19	6	13	
Bilingual environment	24	11	13		20	8	12	
Used to play at home	22	22	0		15	15	0	
Stressed child	22	3	19		15	2	13	

Task	Outcome	Pre	Post	t	CIlow	CIhigh	df	p.adj	Effect
Behavioral Regulation Index	EVIP	105,35	113,85	'2,21	'16,12	'0,88	116,72	0,07	
	CPM	19,97	24,27	'4,28	'6,29	'2,31	110,77	<.0001	***
	HBT	15,81	17,48	'2,84	'2,84	'0,5	86,94	0,02	*
Behavioral Regulation Index	Behavioral Regulation Index	45,46	45,10	0,18	'3,74	4,46	65,36	0,94	
	Inhibition	17,23	16,94	0,36	'1,36	1,95	65,58	0,85	
	Flexibility	11,98	12,03	'0,09	'1,21	1,11	72,26	0,94	
	Emotional Control	16,31	15,94	0,38	'1,56	2,3	65,29	0,85	
	Initiative	12,36	12,52	'0,21	'1,6	1,29	64,99	0,92	
	Working Memory	15,98	15,63	0,41	'1,36	2,06	68,62	0,85	
	Organisation	10,86	10,65	0,27	'1,33	1,75	72,53	0,89	
General Adaptation	General Adaptation	35,23	34,74	0,56	'1,27	2,26	57,98	0,82	
	Social Behavior	43,43	43,71	'0,38	'1,75	1,19	56,89	0,85	
	Problem Internalization	32,07	31,06	1,64	'0,23	2,23	48,47	0,20	
	Problem Externalization	39,47	38,74	0,84	'1	2,45	58,97	0,61	
	Depressed? Happy	30,20	30,13	0,42	'0,27	0,41	58,04	0,85	
	Anxious? Confident	31,43	30,19	1,93	'0,07	2,55	31	0,13	
	Irritable? Tolerant	38,77	38,55	0,13	'3,34	3,8	59,99	0,94	
	Isolated? Integrated	42,60	42,16	0,49	'1,36	2,24	58,95	0,85	
	Aggressive? Controlled	43,40	42,58	0,71	'1,5	3,14	58,87	0,71	
	Egoist? Prosocial	45,73	45,61	0,08	'2,82	3,07	56,37	0,94	
	Resistant? Cooperative	47,70	48,26	'0,33	'3,95	2,83	56,68	0,85	
	Dependent? Autonom	50,10	51,03	'0,59	'4,11	2,25	54,65	0,81	
	Planning	Planing	1,46	2,27	'5,46	'1,11	'0,52	76,19	<.0001
Role		2,06	2,73	'3,39	'1,06	'0,28	100,61	<.001	**
Propels		2,63	3,45	'4,15	'1,21	'0,43	99,47	<.0001	***
Language		2,13	2,67	'2,52	'0,95	'0,11	97,27	0,04	*
Scenario		2,19	2,80	'3,02	'1,01	'0,21	99,49	0,01	*

Task	Outcome	Cohen,d	$\sigma$ (Cohen,d)	OSlow	OSHigh	t	p.val	N	R <sup>2</sup>	
Performance	TR,(ms)		0,22	0,22	0,65	0,20	1,033	0,311	60	0,732
		CC	0,19	0,22	0,61	0,23	0,894	0,380	60	0,735
		CI	0,10	0,26	0,60	0,41	0,381	0,706	60	0,621
		IC	0,12	0,22	0,56	0,31	0,547	0,589	60	0,716
	PRC,(%)	II	0,41	0,25	0,90	0,08	1,641	0,113	60	0,643
			0,00	0,28	0,54	0,55	0,017	0,987	60	0,551
		CC	0,05	0,32	0,67	0,58	0,148	0,884	60	0,422
		CI	0,23	0,25	0,72	0,26	0,929	0,362	60	0,644
	MFT,(dB)	IC	0,02	0,28	0,56	0,52	0,074	0,941	60	0,560
		II	0,04	0,29	0,61	0,54	0,132	0,896	60	0,508
			0,09	0,34	0,75	0,58	0,26	0,80	42	0,643
		CC	0,50	0,40	1,28	0,28	1,26	0,23	42	0,505
	Cognitive	CI	0,14	0,40	0,64	0,92	0,35	0,73	41	0,490
		IC	0,27	0,31	0,33	0,88	0,89	0,39	42	0,701
		II	0,11	0,24	0,57	0,36	0,46	0,66	42	0,825
		Power_peak	0,10	0,36	0,60	0,81	0,29	0,78	42	0,594
EVIP		0,06	0,25	0,54	0,43	0,234	0,816	60	0,651	
Personality	CPM	0,35	0,24	0,13	0,83	1,432	0,164	60	0,661	
	H3T	0,18	0,26	0,70	0,33	0,707	0,486	60	0,611	
	Behavioral Regulation Index	Behavioral Regulation Index	0,35	0,45	0,54	1,24	0,778	0,462	31	0,831
		Inhibition	0,00	0,45	0,89	0,89	0,000	1,000	31	0,833
Flexibility		0,54	0,54	0,51	1,59	1,007	0,343	33	0,713	
Emotional Control		0,36	0,50	0,61	1,34	0,732	0,485	32	0,745	
Initiative		0,50	0,44	1,36	0,36	1,141	0,287	31	0,796	
Working Memory		0,00	0,64	1,25	1,25	0,000	1,000	32	0,676	
CBQ	Organisation	0,24	0,52	0,78	1,26	0,46	0,655	34	0,670	
	General Adaptation	0,57	0,23	1,02	0,13	1,525	0,040	31	0,952	
	Social Behavior	0,43	0,34	1,10	0,24	1,257	0,249	31	0,891	
	Problem Internalization	0,35	0,37	1,07	0,37	0,957	0,370	31	0,875	
	Problem Externalization	0,00	0,31	0,61	0,61	0,000	1,000	31	0,909	
	Depressed Happy	0,00	0,00	0,00	0,00	0,061	0,953	31	1,000	
	Anxious Confident	0,00	0,00	0,00	0,00	0,155	0,881	31	1,000	
	Irritable Tolerant	0,25	0,47	1,17	0,67	0,531	0,612	31	0,792	
	Isolated Integrated	0,93	0,43	1,76	0,09	1,171	0,067	31	0,830	
	Aggressive Controlled	0,37	0,25	0,86	0,11	1,507	0,175	31	0,943	
	Egoist Prosocial	0,22	0,55	0,87	1,30	0,391	0,707	31	0,713	
	Resistant Cooperative	0,08	0,43	0,77	0,93	0,192	0,853	31	0,825	
Dependent Autonomous	0,14	0,53	0,89	1,17	0,265	0,798	31	0,740		
Cognitive Behavioral Therapy	Planing	0,85	0,27	0,32	1,39	3,126	0,005	51	0,703	
	Role	0,78	0,32	0,15	1,41	2,434	0,024	51	0,586	
	Propels	0,76	0,31	0,16	1,36	2,467	0,023	51	0,622	
	Language	1,03	0,26	0,53	1,54	3,889	0,001	51	0,731	
	Scenario	0,93	0,28	0,37	1,48	3,288	0,004	51	0,681	