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Training executive function in preschoolers reduce externalizing behaviors

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ABSTRACT

In this research we want to observe, in preschool children, and with an experimental design, whether a cognitive intervention aiming at enhancing inhibition capacities would have an impact not only on executive functions but also lead to behavioral changes with a decrease in external behavioral problems (EB).

Forty-seven normally developed preschoolers (mean age of 60 months) took part in a pretest assessing executive function (EF) capacities (attention, motor and cognitive inhibition, flexibility and working memory) and behavior (questionnaires and an observational paradigm for externalizing behaviors). Children were then randomly allocated to either a control (n=23) or an experimental group (n=24). Both groups participated in 2 45-min sessions per week for 8 weeks. Children from the control group took part in handicraft sessions and children from the experimental group received inhibition-training sessions. The latter consisted of a series of games/exercises aimed at increasing the different components of inhibition functions (interrupt an ongoing response, impulsivity management, inhibition of a predominant response, inhibition of external distractors) and involving the use of fictional characters aimed at improving the child's metacognition relative to those functions. At the end of the intervention, every child from each group took part in the post-test.

We observed significant differences between control and experimental groups, with the latter group performing better on inhibition, attention and working memory measures. More importantly, differences were also measured on behavioral measures of inattention, and on negative reaction in an observational paradigm. We thus show that it is possible to enhance EF capacities in preschoolers and that this has an impact on EB.

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1. Introduction

In children, executive functions (EF) are necessary to regulate behavior in social or academic situations, but also to control impulsive behaviors and to follow parents' or teachers' instructions. We all know children who have difficulty restraining themselves from touching attractive games in a shop despite their parents' prohibition, who cannot refrain from making inappropriate remarks in public places, or who have difficulty waiting their turn when playing a game. In all these situations, these children would need good *inhibition* capacities to overcome these difficulties. When teachers ask a class to do an exercise, children first need to pay *attention* to what he/she says and have good *working memory* to remember the different instructions. Then, when another exercise is presented, children need good *flexibility* capacities to switch from one set of instructions to another one. EF are thus needed in many situations. They are developed throughout childhood and become mature in adolescence, but the most significant growth occurs in the preschool period [1,2]. It is thus particularly interesting to observe this period of development.

Studies on typically developing preschoolers have repeatedly shown correlations between EF and externalizing behaviors (EB). EB cover difficult behaviors such as aggression, opposition, and impulsivity, and are one of the most frequent motives for psychological consultations in young children. Floyd and Kirby [3] showed, in 70 children aged 3 to 5 years, a correlation between inhibition capacities measured by Stroop and Go–NoGo tasks and evaluation of inattention and aggression symptoms, but not hyperactivity (Behavioral Assessment System for Children Teacher Rating Scale; [4]): children with good inhibitory capacities had less behavioral inattention or aggression. Livesey et al. [5] also showed, in 36 children (5 and 6 years) that those with more EB (evaluated by the teacher Rowe Behaviour Rating Inventory, [6]) had worse performance in the Day/Night test but not in a Stop Signal task. More recently, Olson et al. [7] showed that the association between low capacity of inhibitory control (measured by a

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composite score from a tapping task, a task like Day–Night and a Stroop task type) and a high level of EB (measured using the Child Behavior Checklist—CBCL; [8]) were present in both Japanese (59), Chinese (59), and Americans (58) 4 years children.

Other studies have tested the link between EF and EB in clinical samples of preschoolers with EB disorders and have reached similar conclusions. Children with EB showed deficits in executive functions compared to a control group [9–15].

In both populations, it is mainly inhibition that correlates with EB: there is generally a higher error rate in inhibition tasks in children with more EB [10–20]. Moreover, other research in typically developing samples report that measuring inhibition abilities at preschool age significantly predicts EB one year later [21], two years later [22] or even after three years [23].

Recently, two meta-analyses were published on the relation between EF and EB in preschoolers. In the first one, Pauli-Pott and Becker [24] reviewed 25 studies testing the association between EF performance and the presence of ADHD symptoms (hyperactivity, impulsivity and inattention). They found that these ADHD symptoms were weakly associated with flexibility and working memory measures but presented a moderate to high correlation with attention-vigilance measures ($r=.27$), interference control ($r=.26$, e.g., Stroop test) and inhibition ($r=.29$, e.g., in a Go–NoGo task). The second meta-analysis was done by Schoemaker and collaborators [25] who reviewed studies not only on ADHD groups of preschoolers but also on those showing EB or ODD (Oppositional Defiant Disorder). They observed that EB was related to an overall EF factor ($r=.22$) as well as to inhibition specifically ($r=.24$), whereas effect size was smaller for working memory ($r=.17$) and flexibility ($r=.13$). In addition, they showed that these relations were stronger in older preschoolers ($4^{1/2}$ years to 6 years) relative to younger ones (3 years to $4^{1/2}$ years), and especially in referred samples.

Executive capacities seem thus to play a significant role in the growing control of EB in preschoolers. However, all these studies are correlative in nature. A more direct way to test the causal relationship between EF and EB is to manipulate EF and examine the impact of this on EB. With older children, a few studies showed that working on a child's executive function could have a positive impact on his/her EB. For instance, Riggs et al. [26] showed, in 329 school-age children (between 7 and 9 years), an improvement of inhibition capacities with the PATHS Curriculum (Promoting Alternative Thinking Strategies; [27]), and also showed that children who benefited from the program, focusing among other things on self-control and problems resolution, showed less EB one year later, in comparison with a control group. However, PATHS is a school-based prevention curriculum aimed at reducing behavior disorders by developing social–emotional competencies in children, with an emphasis on the developmental integration of cognition, affect, and behavior. Accordingly, as this program had an impact on affect and emotional language as well as on EF, it is not easy to determine if the behavioral improvement is due to an increase of inhibition capacities or to the more socio-emotional nature of the intervention.

Noël et al. [28] used a specific inhibition capacities training program in 6 ADHD children (8–10 years) staying in hospital. These authors showed that this training significantly increased not only inhibition capacities but also attention abilities and other EF. More importantly, children who benefited from this intervention were evaluated by the nurses as better on the hyperactivity index of the Conners rating scale [29]. This therefore calls for a direct causal link between EF and EB but the study was conducted on a very small sample of children.

More recently, Tamm et al. [30] observed the impact of an attention training program on behavior in school-aged ADHD children (7–15 years). They observed fewer ADHD symptoms on SNAP-IV Inattention and Hyperactivity rating scales [31] as evaluated by parents and improvement on the Clinical Global Impressions (CGI; [32]) as evaluated by clinicians, but no significant improvement in the teachers' ratings. The authors also showed an improvement in executive functioning ratings from parents and clinician (questionnaires), but they failed to find any improvement in neuropsychological measures.

To our knowledge, the only study about intervention in preschoolers focusing on the cognition side is the research of Tamm et al. [33]. They showed that a training program which used exercises/games focusing on a variety of cognitive functions (inhibition, memory, attention, hand-eye coordination, etc) and which also taught parents how to do the work of interventionists at home, could lead to an improvement in attention and working memory. They also observed improvements in parents' and clinicians' ratings of the child's inattention. They did not observe any effect on inhibition or on behavioral measures such as hyperactivity or impulsivity, nor on the manifestations of ADHD in the classroom (SKAMP classroom). However, this study does not provide much information on the causal relationship between EF and EB. Indeed, first this intervention targeted many cognitive functions and was thus not restricted to the training of EF per se. Second, the interventionists also taught the parents elementary principles of the behavioral approach to decrease the child's inappropriate behavior, so that it is impossible to disentangle the effect of this behavioral practice from the effect of the cognitive training. Third, they did not use a control group to ensure that the observed improvements were not actually due to the spontaneous evolution of the child.

Yet several studies have developed specific training aimed at increasing EF in preschool children and have showed that it is possible to improve inhibition capacities [2,34–36], working memory capacities [36,37] or EF in general [38]. However, none examined the possible impact of that EF improvement on the child's EB.

In summary, the literature shows a significant association between EF and EB in preschoolers and an ability to predict EB from EF capacities measured up to three years earlier. To directly test the causality of this relationship, one can manipulate EF and examine the impact of this on EB. A few studies have shown that is possible to train EF functions in preschoolers, but none of them looked at the effect of this on children's behavior. A few studies tried to address this issue in older children and seem to suggest a possible effect of EF training on the child's behavior, although some methodological issues have been raised.

Accordingly, the aim of our research is twofold. First, we want to test, in an experimental design, if whether a cognitive intervention aimed specifically at enhancing preschoolers' inhibition capacities is effective. We chose to focus on the inhibition dimension of EF because it has been shown to be the dimension most strongly associated with EB. Second, we want to test whether the training also enhances executive functions beyond inhibition. Finally, and more importantly, we want to test whether this inhibition intervention also leads to behavioral changes with a decrease in EB problems, as we know the strong link between inhibition and EB [24,25].

2. Method and materials

2.1. Procedure

All children took part in a pretest involving the assessment of IQ, executive functions (visual and auditory attention, motor and cognitive inhibition, flexibility and working memory) and behavior (an observational paradigm for EB and questionnaires filled out by teachers and parents). The total testing duration was approximately 60–75 min per participant, so we saw each participant twice. Each participant was tested individually at school in a quiet room. We were careful to alternate verbal and non-verbal tasks.

Children were then randomly allocated to either control or experimental groups. Both participated in 2 45-min sessions per week for 8 weeks. While children from the control group (2 groups of 8 children and 1 group of 7 children) took part in handicraft sessions, children from the experimental group (6 groups of 4 children) had inhibition training sessions. All sessions took place in the child's school in a room separated from the child's class.

At the end of the intervention (8 weeks after pretest), every child from each group took part in the post-test (same baseline as in pretest, except for IQ). At the very end of this study, we went back to the schools to explain our results to the teachers who were involved in the research.

2.2. Participants

Forty-seven typically-developing children (14 boys, 33 girls) were recruited in preschool classes in the French part of Belgium. Parents received an information letter and a consent form in the schoolbag of their child. After we received agreement from parents and teachers, children were seen at school for testing and intervention. Children were between 50 and 69 months old (*M* age=60.32 months, SD=4.76). They were randomly distributed between experimental versus control group, taking into account four variables (sex, school, age and laterality). Parental level of education was evaluated using a seven-point scale from low (incomplete elementary school) to high (university) education. Mean for mother's level of education was 4.98 (SD=1.27), with 4.36 for fathers (SD=1.56). For monthly income (including any source of net income, for both parents), we used a nine-point scale from low (0–500 euros) to high income (more than 4000 euros). Mean was 6.00 with a standard deviation of 1.82, which corresponds to an income of 2500–3000 euros a month.

2.3. Instruments

There has been a large variety of means used to test the effectiveness of interventions. Some studies have used other-reported measures without taking into account direct measures like cognitive tests [39]; conversely, others have used only objective measures [38]; and few studies have assessed the transfer of acquisition to cognitive functions other than the trained one. In this study, we wanted to assess the effect of specific inhibition training on executive functions and behavior, both by direct and indirect measures.

2.3.1. Exclusion criteria

We excluded children with neurodevelopmental or psychiatric disorders. We also used an intelligence scale to exclude mental retardation.

2.3.1.1. Wechsler preschool and primary scale of intelligence (WPPSI-III—[40]). We used four subscales of WPPSI-III [40] in pretest to exclude possible mental retardation. These four subscales were "Information" and "Verbal reasoning" from the verbal scale and "Matrix" and "Block design" from the performance scale. Mean of each of WPPSI-III's subtests is 10, with a standard deviation of 3. We included in this study children having a global score between 5.5 and 14.5 (±1.5 SD). This global score was the mean of the four subscales.

2.3.2. Attention

2.3.2.1. Cats [41]. The *cats* task is a cancellation task measuring selective visual attention. The child had to cancel as many cats as possible without paying attention to distractors. Maximum duration is 180 s. The child is asked to be as fast as possible. Our measure is the precision (number of correct responses minus errors).

2.3.2.2. Auditory attention [41]. In this task, the child listens to an audio recording and has to put a red square in a box when and only when he/she hears the word "red". Precision score is calculated by subtracting errors from correct responses.

2.3.3. Inhibition/flexibility

2.3.3.1. Cat–dog–fish [42]. The cat–dog–fish task is a task inspired by the Day/Night test [43] which assesses inhibitory control. There are two conditions: in the *control condition*, a card of 24 drawings (cats, dogs and fish) is presented to the child. He/she must name the images on the card as quickly as possible and without error. In the *inhibition condition*, we tell the child that, on Mars, "cats" are called "dogs", "dogs" are called "cats" and fishes are called fishes (in French, the word for "cat" (chat) is very close phonologically from the word "dog" (chien)). The child is invited to follow the new rule and give the "Martian" animal names for the animals on the second card as fast as possible and without error. The number of correct responses is scored.

2.3.3.2. Monster Stroop [44]. This task assesses inhibition of external distractors and flexibility. It is composed of 3 cards in A4 format. In the first *control condition* (naming), 6 rows of little monsters of different colors (red, blue, green or yellow) are presented to the child. Each monster is depicted in a white square. The child has to name, as quickly as possible and without error, the color of the monsters. Two conditions are then presented to the child: an inhibition and a flexibility condition. In the *inhibition condition*, the monsters are presented in squares of different colors and the child has to name, as quickly as possible and without making any error, the color of the monsters. He/she must therefore inhibit distractive information (background color of the square) to focus his/her attention on the target information (monsters color). This condition therefore involves inhibitory control. Then, a third card similar to the previous one is presented to the child. The difference is that some of the monsters are drawn upside down. The child must quickly and without error name the color of the monsters that are right-side-up and name the background color when the monsters are upside-down. The number of correct responses is scored.

2.3.3.3. Traffic lights task [45]. The traffic lights task is a task of spatial incompatibility inspired by the dots task of Davidson et al. [45], also used by Diamond et al. [34]. We developed this task with E-Prime Software [46]. There are three conditions: two simple conditions and a mixed one. The first condition is a *congruent condition:* the child sees a green traffic light appearing either on the left or on the right of a cross and has to press a button as quickly as possible on the side of the green traffic light. The second condition is an *incongruent condition:* the traffic light is now red and the child has to press the button on the side opposite to the traffic light. In this case, the child must inhibit the predominant response (pressing on the same side as the stimulus). Finally, the third flexibility condition is a *mixed condition*: green and red traffic lights are mixed and the child is asked to press on the same side as the light when it is green and on the opposite side when it is red. Both the first and the second conditions include 20 trials preceded by 4 training items. The third condition includes two blocks of 20 trials each, preceded by 8 training items. The presentation order of the trials is fixed, with the constraint that there cannot be more than 3 of the same response in a row (for simple conditions) or 3 of the same condition (for mixed condition). For each trial, the sequence is as follows: A white screen appears for 500 ms, then a fixation cross appears ("+" centered on the screen, in Courier New 20 bold) and stays on the screen for 500 ms. This is followed by the appearance of a traffic light which remains on the screen until the child responds. Response keys correspond to the letters "S" and "L" on an AZERTY keyboard. Number of correct responses is scored.

2.3.3.4. Head–Toes–Knees–Shoulders [47]. This task was originally composed of 3 parts; we have added a fourth at the end. In the first part, the child is asked to touch his/her head when the examiner says "touch your feet", and to touch his/her feet when the examiner says "touch your head". In the second part, shoulders and knees are added. The child must now touch his/her knees when the examiner said "touch your shoulders" and vice versa, in addition to the two instructions in Part 1. In the third part, the rules are changed: the child must now touch his/her knees when the examiner said "touch your head" and touch his/her shoulders when he says "touch your feet" (and vice versa). This third part is administered only if the child has correctly answered at least 5 of the 10 items in Part 2. We created a fourth part, which is always performed, in order to test flexibility. In this part, there are two hoops on the floor, a red one and a blue one. When the examiner is in the blue hoop, the child has to do what the examiner says (i.e., to touch his/her head when the examiner says "touch your head" and to touch his/her feet when told to do so). However, when the examiner is located in the red hoop, the child must do the opposite and touch his/her feet when told to touch his/her head (and vice versa). At the beginning of each part, there are 8 practice items to ensure that the child understands the rule. The number of correct responses for each part is calculated.

2.3.4. Working memory

2.3.4.1. Word span [48]. The word span task was used to assess verbal short-term memory (phonological loop). In this task, the examiner presents a series of words to the child (one per second), who is asked to repeat them in the same order. The first level of difficulty includes two words, and one more word is added for each new level. Each level of difficulty has three trials and if the child fails at least two out of the three trials, then the task is stopped. We used the corrected span as the dependent measure: this is the longest sequence for which two series were repeated correctly, plus .5 if one longer series was also correctly processed.

2.3.4.2. Block tapping test [48]. The block tapping test (initially developed by Corsi [49]) is a measure of short-term memory of visuospatial information (visuospatial sketchpad). The examiner and the child sit face to face with a board between them, onto which are glued nine identical cubes. The child has to imitate the path of the examiner, who touches sets of cubes of increasing number. There are, as for the word span task, three trials per level. We again used the corrected span as the dependent measure.

2.3.4.3. Categospan [48]. This complex span task was used to assess the central executive. The examiner orally presents one-syllable food or animal words which the child must then repeat by category, first naming the foods items, then the animals. Trials with items drawn on cards are performed first to ensure that the child understands the instructions, and pictures of a forest and a plate are presented to the child to help recall animal and food names, respectively. There were again three trials per level, with trial set length increasing in each level. We again used the corrected span as the dependent measure.

2.3.5. Externalizing behaviors

2.3.5.1. Unfair Card Game [50]. The Unfair Card Game (UCG) is inspired by an adult paradigm focusing on perspective-taking [51] and is based on a cooperative computer game where the child is invited to play with a virtual child named Thomas. It has been designed to induce spontaneous positive affects, negative affects, agitation and inattention. The game is presented to the child as a game where he/she can win candy. The child sits at a table facing the computer, next to the examiner. When the game starts, instructions are given to the child by a virtual examiner (a previously video-recorded adult). Two cards are shown on the screen; on one of them there is a picture of a piece of candy. Then the cards turn over and start to move. When the cards stop moving, the child must indicate which is the card with the candy. The child is invited to play five rounds. For each correct answer, he/she gives a piece of candy to Thomas, his virtual partner. After the first five rounds, it's time for Thomas to play. It is explained that a candy will be given to the child for each of Thomas's correct response. However, the game is rigged such that the child wins his/her five rounds and therefore wins Thomas five pieces of candy (this is called the winning phase), but Thomas wins only one round, so the child receives only one piece of candy (losing phase). At the end of the game, Thomas tells the child that he played badly and that he will therefore share his candies with the child. In this way, the level of frustration of the child returns to normal. This game last 10 min. The advantage of this observational paradigm is that we can control the reaction of the adversary, as each child is faced with the same virtual partner (Thomas). The speech of the examiner is also strictly standardized (comments made at the end of each round, for the two phases). The UCG is video-recorded and coded following standardized guidelines. Four dimensions are coded: positive affect (smile, laughter, etc), negative affect (tears, insults, etc), agitation (movements) and inattention (distraction). For each of these dimensions, the frequency and the intensity is taken into account when coding, using a 5-point Likert scale ranging from 1 (neither frequent nor intense) to 5 (very frequent and intense). Coding was done by trained coders. The intercoders' reliability, calculated with the weighted Kappa coefficient, reaches .766.

2.3.5.2. Conners rating scale [29]. We asked parents and teachers to fill in the Conners parent and teacher rating scale (CPRS, CTRS) for each child tested. These questionnaires, measuring parents' and teachers' perception of child hyperactivity, inattention, impulsivity and conduct disorders, are composed of 48 items in the parent version and 28 items in the teacher version. Adults must choose whether the statement represents a common behavior of the child (four-point Likert scale from "not at all" to "very much"). Inattention, hyperactivity, impulsivity and conduct disorder factors are calculated as the sum of the respondents' ratings of the relevant observed behaviors. T-scores are then calculated and taken into account in our analysis.

2.4. Inhibition training

Each 45 min session was held by an experienced neuropsychologist and a psychology trainee. Particular emphasis was placed on the proximal zone of development: it was important that the games were neither too easy, such as would risk causing boredom in the children, nor too difficult, such as would risk causing discouragement or dropping out. The intervention program included exercises/games tapping on the four components of inhibition functions: interruption of an ongoing response, impulsivity control, inhibition of a predominant response and inhibition of external distractors (see Appendix A for a description of the exercises proposed in each training session). In addition, we progressively introduced fictional characters to the children to improve their metacognition of executive functioning. These characters were inspired by *Reflecto* [52], an intervention method using metacognition by introducing eight characters, each with a different job representing one of the EF. The use of the jobs metaphor allows activation, in a single image, of a set of mental representations already present in the child's repertoire. In this present study, children first "met" the *policeman* showing a stop signal and learnt a little song associated with him: "Stop: first I think and then I do." This character was involved in all exercises involving inhibition of a predominant response. Children were reminded to "use their policeman" in those exercises to help them not to go too fast or too impulsively. The second character was the *statue* who helped them to be still during exercises involving motor control. The person leading the training session also invited children to be aware of and share which body part tends to move most often or is most difficult to keep still. The child was then encouraged to pay attention to that part of the body and to learn to control this part. The pictogram of the statue was presented before any activity that required calm or when a child was stirred for a game. The last character introduced was the *detective*, who helped each child to check whether he/she had made any errors in the game as well as to check the performance of others. Thanks to these characters, children learned which function was most involved in which games. Although the sessions were led in groups, every child was always in action, even if it was not his/her turn to answer, as he/she also had to check the others' responses for mistakes. Feedback was given to the children continuously during the games using the characters. For example, in a game focusing on the control of a dominant response, children received a "policeman card" each time they correctly answered. By contrast, when a child gave an answer when it was not his/her turn, or he/she did not interrupt an ongoing response, the person leading the training session notified the child verbally, and the child lost one of his/her policeman cards.

Each of the six intervention groups were composed of four children. We choose to work by group as we think that children of this age can benefit from the help of their peers in these kinds of sessions. Before starting each new game, the person leading the training session ensured that all children in the group had understood the rules. Some of the games were for the whole group, some others were by pairs (e.g., day/night exercises). Most of the time, we used material from commercialized games with the rules altered to ensure that we specifically and effectively trained inhibition. In this way, at the end of the intervention, it was easy for parents to get these games at home.

Children from the control group took part in handicraft sessions (same number of sessions and same duration as the experimental group). Three subgroups were created: two of 8 children and one of 7 children. The person leading the session provided an ample supply of crafting materials to the children. Children were told that they had lots of materials available to them on a table and that they could make anything they wanted with them and take it home. They were also told to respect the rules of the group (no degrading the equipment, no screaming, no fighting, etc).

3. Results

3.1. Data analysis

First of all, the reliability of the tests we developed for this project was measured by calculating Cronbach's alpha on data collected at the pretest. This measure was excellent for the inhibition condition of the cat–dog–fish (.92), acceptable for the Monster Stroop task in the inhibition (.60) and flexibility (.70) conditions, very good for the incongruent trials of the traffic lights (.88) and acceptable for the new condition of the *Head–Toes–Knees–Shoulders* (.60).

As there exists no pure measure of EF (since EF always involve something else, like naming, motor response, color detection, etc.), we calculated factors that accounted for the common variance of the different tasks tapping each specific executive function. We then tested whether the control and the experimental groups were equivalent in pretest, as subjects were randomly allocated to one of the two groups. Finally, to measure the effectiveness of the intervention, we calculated repeated measures ANOVAs with one within-subject factor, the Time (pre and post-test) and one between-subjects factor, the Group (control and experimental group). These analyses were run on each of the four EF factors and on the behavioral measures. When a significant or marginal time-by-group interaction emerged, paired-samples t test for separated groups were calculated to measure the improvement of each group thanks to the training. Effect sizes were calculated using partial eta square (η_p^2). The level of significance for all tests was set at .05.

3.2. Factorial analyses

We need to notice that in all our analysis, we never mentioned reaction times variables. First because some tasks were not timed and so we could not insert them in our factor analysis, second because when we observed each task separately, we did not find significant results on reaction times. May be because our intervention was not focused on speed but more on accuracy.

We used a factorial analysis in principal components forced to one factor to aggregate tasks from the pretest measuring the same function. Table 1 shows the distribution of tasks on the four factors, as well the loadings of each task into the factor. A first factor was calculated on tasks measuring inhibition: we used the number of correct responses for the inhibition parts of Traffic Light, Cat–Dog–Fish, Monster Stroop and HTKS (for HTKS we used the sum of the three first inhibition parts). The saturation of tasks on this Factor ranged from .379 to .790, and it accounted for 44.5% of the variance. A second factor was calculated on the tasks measuring attention: we used precision for Cats and Auditory Attention (precision = number of correct response minus errors). The saturation of each task was .718, and it accounted for 51.5% of the variance. The third factor was calculated on tasks measuring working memory (correct span for Categospan, Words span and Block Tapping Test). It explained 51.2% of the variance, and the saturations ranged from .501 to .849. Finally, a last factor 4 was calculated on tasks measuring flexibility (number of correct responses for the flexibility parts of Traffic Light, Monster Stroop and HTKS), and the saturation of tasks on this factor ranged from .436 to .872. This factor accounts for 54.1% of the variance. As often reported in the literature [53-55], we observe good correlations between the four factors (see Table 2). On the basis of those analyses, we calculated a factorial score for each factor at pretest and post-test.

3.3. Between group comparisons in pretest

Testing of the equivalence of the two groups in pretest is reported in Table 3 and shows no significant differences between the two groups for all demographic, cognitive and behavioral measures. We only observed a significant difference in the hyperactivity index and impulsivity in the CPRS (parent scale). As we did not observe any difference concerning either the hyperactivity index in the CTRS (teacher scale) or inattention and agitation in the UCG, we consider the groups sufficiently to be equivalent in pretest.

Table 1
Tasks loadings for the four factors resulting from the factorial analysis on the data in pretest.

Tasks	Loadings on the factor
Factorial analysis for inhibition	
Traficlight CR[a]	.790
Cat–dog–fish CR[a]	.772
Monster Stroop CR[a]	.646
HTKS[a]	.379
% of Explained variance	**44.5**
Factorial analysis for attention	
Cats precision (CR–Err)	.718
Auditory attention precision (CR–Err)	.718
% of Explained variance	**51.5**
Factorial analysis for working memory	
Categospan	.849
Words span	.750
Block tapping test	.501
% of Explained variance	**51.2**
Factorial analysis for flexibility	
Traficlight CR[b]	.872
HTKS[b]	.819
Monster Stroop CR[b]	.436
% of Explained variance	**54.1**

[a] Correct responses for the inhibition parts.
[b] Correct responses for the flexibility parts.

Table 2
Intercorrelations among the four factors in pretest.

Variable	1	2	3	4
1. Inhibition factor	–	.469**	.573**	.696**
2. Attention factor		–	.304*	.372*
3. Working memory factor			–	.572**
4. Flexibility factor				–

* $p \leq .05$.
** $p \leq .01$.
*** $p \leq .001$.

3.4. Effect of the intervention

3.4.1. Inhibition

A repeated measures ANOVA on the inhibition factor showed a significant main effect of time ($F(1,45)=23.463$, $p<.001$, $\eta_p^2=.343$), no main effect of group ($F(1,45)=.480$, $p=.492$) but a marginal time-by-group interaction ($F(1,45)=3.649$, $p=.062$, $\eta_p^2=.075$) (see Table 3). Paired-samples *t* test indicated that the experimental group significantly improved from pre- to post-test, $t(23)=-5.273$, $p<.001$, which was not the case for the control group, $t(22)=-1.898$, $p=.071$ (see Fig. 1).

We then wondered whether some characteristics of the different children themselves could account for the differential benefit of the intervention. First, we split the group according to the median age (60 months). The repeated measures ANOVA on the inhibition factor with time as the within-subject factor and age as the between-subjects factor showed an effect of time ($F(1,22)=29.650$, $p<.001$, $\eta_p^2=.574$), an effect of age group ($F(1,22)=18.702$, $p<.001$, $\eta_p^2=.459$) but no time-by-age-group interaction ($F(1,22)=2.523$, $p=.126$). This indicated that young children benefited more from the intervention (improving mean=8.90; sd=7.92) than older ones (improving mean=4.88; sd=3.77). Second, we split the group in two according to the level of inhibition measured in the pretest. The repeated measures ANOVA (with age used as a covariate) showed no effect of time ($F(1,21)=.164$, $p=.689$) but a significant group effect ($F(1,21)=4.504$, $p=.046$, $\eta_p^2=.177$) and a significant time-by-inhibition-level interaction ($F(1,21)=5.506$, $p=.029$, $\eta_p^2=.208$). Indeed, children who started with a low level of inhibition benefited more from the intervention (improving mean=10.12; sd=7.70) than those who had a higher level of inhibition in pretest (improving mean=4.16; sd=3.41). It is however important to note that high-level children did not present ceiling effect in pre- or post-test and had thus the possibility to improve their inhibition capacities.

3.4.2. Attention

The repeated measures ANOVA calculated on the attention factor showed a significant main effect of time ($F(1,45)=6.631$, $p=.013$, $\eta_p^2=.128$) and of group ($F(1,45)=4.858$, $p=.033$, $\eta_p^2=.097$) qualified by a significant time-by-group interaction ($F(1,45)=16.844$, $p=<.001$, $\eta_p^2=.272$) (see Table 3). Paired-samples *t* test indicated that the experimental group significantly improved from pre- to post-test, $t(23)=-6.267$, $p<.001$, which was not the case for the control group, $t(22)=.892$, $p=.382$ (see Fig. 1).

3.4.3. Working memory

The repeated measures ANOVA calculated on the working memory factor showed a significant main effect of time ($F(1,45)=24.290$, $p=.000$, $\eta_p^2=.351$), no main effect of group ($F(1,45)=.219$, $p=.642$) and a significant time-by-group interaction ($F(1,45)=10.226$, $p=.003$, $\eta_p^2=.185$) (see Table 3). Paired-samples *t* test indicated that the experimental group significantly improved from pre- to post-test, $t(23)=-5.551$, $p<.001$, which was not the case for the control group, $t(22)=-1.276$, $p=.215$ (see Fig. 1).

3.4.4. Flexibility

The same analysis conducted on the flexibility factor showed no significant effect at all (time $F(1,45)=.118$, $p=.733$; group $F(1,45)=2.509$, $p=.120$; time × group $F(1,45)=1.287$, $p=.263$). The training thus had no impact on our flexibility measures.

3.4.5. Behavior

The repeated measures ANOVAs calculated on the four dimensions of UCG showed a significant main effect of time for positive affect ($F(1,44)=7.604$, $p=.008$, $\eta_p^2=.147$), agitation ($F(1,44)=5.807$, $p=.020$, $\eta_p^2=.117$) and inattention ($F(1,44)=23.495$, $p<.001$, $\eta_p^2=.348$) with a decrease of these affects from pre- to post-test and no main effects of group for any of these dimensions. More importantly, we found a significant time-by-group interaction for negative affects, $F(1,44)=9.019$, $p=.004$, $\eta_p^2=.170$ (see Table 3). Paired-samples *t* test indicated that the experimental group showed significantly less negative affects after the training, $t(23)=2.429$, $p=.023$, while children from the control group tended to actually show more negative affects in the post-test than in the pretest, $t(21)=-1.821$, $p=.083$ (see Fig. 2). No significant time-by-group interaction was found for positive affects, agitation or inattention.

Concerning the questionnaires (Conners Parent and Teacher Rating Scale), the repeated measures ANOVAs calculated on the *conduct problems* and *impulsivity* scales for parental evaluation did not show any effects at all (all $F_s<1$). For the *hyperactivity* scale, we just observed a main effect of group, showing a decreasing of hyperactivity in the experimental group ($F(1,41)=4.830$, $p=.034$, $\eta_p^2=.105$) but no effect of time ($F<1$) or time-by-group interaction ($F(1,41)=2.695$, $p=.108$). For teacher's rating, the repeated measures ANOVAs calculated on the *conduct problems* scale and the *hyperactivity* scale did not show any significant effects at all (all $Fs<1$). For *inattention*, there was no significant effect of group ($F(1,45)=1.689$, $p=.200$) but a marginal effect of time ($F(1,45)=3.253$, $p=.078$, $\eta_p^2=.067$) and a marginal interaction, $F(1,45)=3.995$, $p=.052$, $\eta_p^2=.082$ (see Table 3). Paired-samples *t* test

Table 3
Mean scores and standard deviations for each group in pre and post-test session and between-group comparisons.

Variables		Pretest		Analysis (t/χ^2)	d Cohen (r)	Post-test		Analysis (F)	Partial eta squares (η_p^2)
		Control group M (SD)	Experimental group M (SD)			Control group M (SD)	Experimental group M (SD)	Group by time interaction	
Demographic datas	Sex (% male)	21.7%	37.5%	−1.17					
	CA (in months)	60.52 (4.42)	60.13 (5.14)	.283					
	Mean of IQ subtests	9.30 (1.60)	9.94 (1.53)	−1.388					
	Mother education (max=7)	5.27 (1.35)	4.71 (1.16)	1.523					
	Father education (max=7)	4 (1.38)	4.68 (1.70)	−1.419					
	Family income (max=9)	5.95 (1.99)	6.05 (1.69)	−.167					
Cognitive measures	Inhibition factor	61.92 (8.32)	61.44 (8.24)	.20		64.91 (8.46)	68.33 (7.16)	3.649†	.075
	Attention factor	33.56 (5.98)	33.51 (7.73)	.026		31.94 (9.55)	40.60 (6.77)	16.844***	.272
	WM factor	6.66 (1.03)	6.15 (1.01)	1.704		6.87 (1.09)	7.12 (.97)	10.226**	.185
	Flexibility factor	54.24 (8.78)	55.87 (6.66)	−.721		52.38 (8.59)	56.87 (7.42)	1.287	
Behavioral measures	UCG positive affects	1.42 (.47)	1.50 (.54)	−.505		1.17 (.34)	1.38 (.50)	.913	
	UCG negative affects	1.30 (.37)	1.50 (.47)	−1.567		1.44 (.50)	1.31 (.40)	9.019**	.170
	UCG agitation	2.03 (.70)	2.24 (.62)	−1.056		1.83 (.70)	1.85 (.66)	.623	
	UCG inattention	2.12 (.60)	1.99 (.81)	.638		1.70 (.76)	1.36 (.46)	.860	
	CPRS conduct problems	43.62 (9.87)	45.42 (9.28)	−.630		45.16 (15.04)	44.96 (7.59)	.478	
	CPRS hyperactivity	43.09 (6.65)	50.42 (9.89)	−2.920**	−.87 (−.40)	44.35 (9.47)	48.22 (9.44)	2.695	
	CPRS impulsivity	43.77 (7.14)	49.42 (10.55)	−2.105*	−.63 (−.30)	44.45 (9.83)	46.87 (8.38)	1.313	
	CTRS conduct problems	48.22 (7.81)	47.71 (5.58)	.258		47.17 (6.74)	47.79 (6.67)	.533	
	CTRS inattention	46.83 (6.17)	46.33 (4.04)	.325		46.96 (7.05)	43.79 (3.36)	3.995†	.082
	CTRS hyperactivity	47.22 (13.06)	45.79 (7.88)	.455		46.35 (12.91)	45.50 (9.45)	.148	

Notes: CA=chronological age; IQ=intellectual quotient; WM=working memory; UCG=unfair card game; CPRS=Conners parent rating scale; CTRS=Conners teacher rating scale.

† $p \leq .10$.
* $p \leq .05$.
** $p \leq .01$.
**** $p \leq .001$.

indicated that the experimental group significantly improved from pre- to post-test, $t(23)=2.375$, $p=.026$, which was not the case for the control group, $t(22)=-.166$, $p=.870$ (see Fig. 2).

4. Discussion

In this study, we wanted to test the effectiveness of an intervention focusing on the four main components of inhibition (interruption of an ongoing response, impulsivity management, inhibition of a predominant response, inhibition of external distractors) in preschoolers and its impact on EB.

In 2007, Diamond et al. showed that a school curriculum emphasizing EF could increase EF in preschoolers. But their training program was not specific and focused on a large variety of EF, their baseline was very short (only two inhibition tasks) and their curriculum was very long (one year), which is not easy to implement in a clinical practice. Moreover, they did not measure the impact on EB. Noël et al. [28] showed that a training program geared specifically toward inhibition could increase EF capacities and improve behavior in a school-aged sample. However, their sample was very small (6 children). Thorell et al. [36] showed that inhibition training in preschoolers could increase inhibition but only for trained tasks. Indeed, they showed no improvement on non-trained inhibition tasks.

In the present research, our first hypothesis was therefore that we would observe an improvement in inhibition capacities after the intervention in preschoolers. Our results showed a tendency to increase performances with respect to inhibition. Indeed, although the repeated measures ANOVA did not reach significance, paired-samples t tests showed that the experimental group significantly improved from pre- to post-test, which was not the case for the control group. Moreover, whereas Thorell et al. [36] did not show any effect on non-trained inhibition tasks after their inhibition training, in our case we observed improvement on non-trained as well as trained inhibition tasks. The fact that the results were moderate could be due to several causes. First, in preschoolers, it might be that more than 16 sessions are necessary to lead to a large improvement. Second, our sessions were conducted in small groups of children who, despite being nearly of the same age, still presented different levels of their inhibition development. We indeed showed that those children who benefited more from the intervention were the younger ones and those who started the intervention with a lower level of inhibition. As we randomly created our groups of four children and adapted the games to the level of the group, it is possible that some children were less challenged by the games than the others. In particular, it is possible that for the older children and those with higher levels of inhibition, the games offered kept them in their comfort zone instead of challenging them in their Proximal Zone of Development. This could possibly be a limit of training in groups which are not constituted on the basis of a strict homogeneity in terms of the cognitive function that is trained.

Second, we also expected a possible transfer to other EF. Indeed, although different EF can be distinguished, it is well known that they cannot be totally dissociated from one another [54]. Furthermore, even if our training was specifically focused on inhibition, children had to keep new instructions in mind for the games, which involves working memory and, when the exercises became more complex, there was also some flexibility component. In preschoolers, few studies have observed the effect of cognitive training of a specific executive function on the other functions, and the results are inconsistent. Thorell et al. [36] showed the effect of a 5 weeks inhibition training (15 min each attended preschool day) on some trained inhibition tasks but not on working memory and attention. Noël et al. [28] also pointed out an improvement of attention capacities after their inhibition training program but they didn't

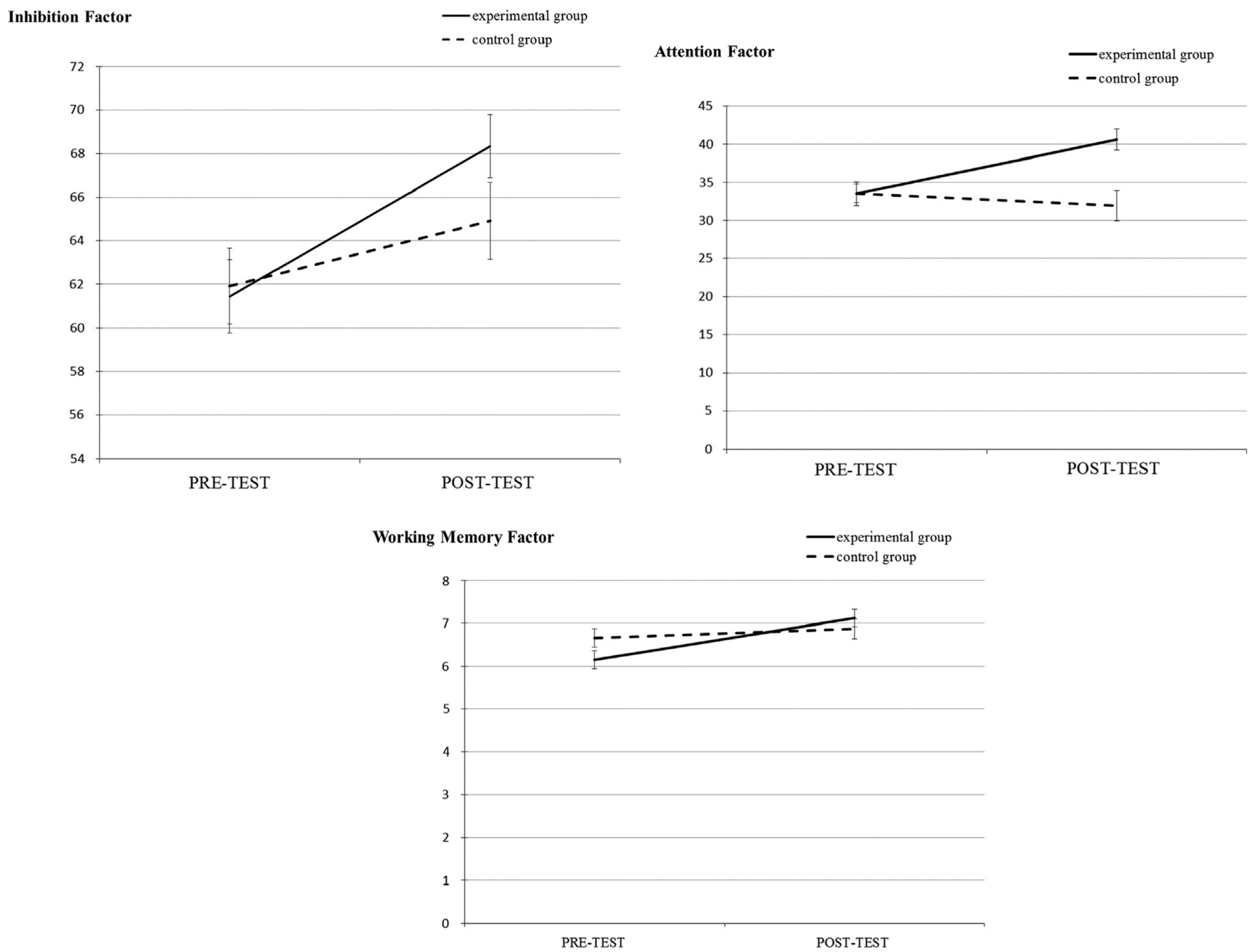

Fig. 1. Profile plots "PrePost * Group" for the inhibition, attention and working memory factors.

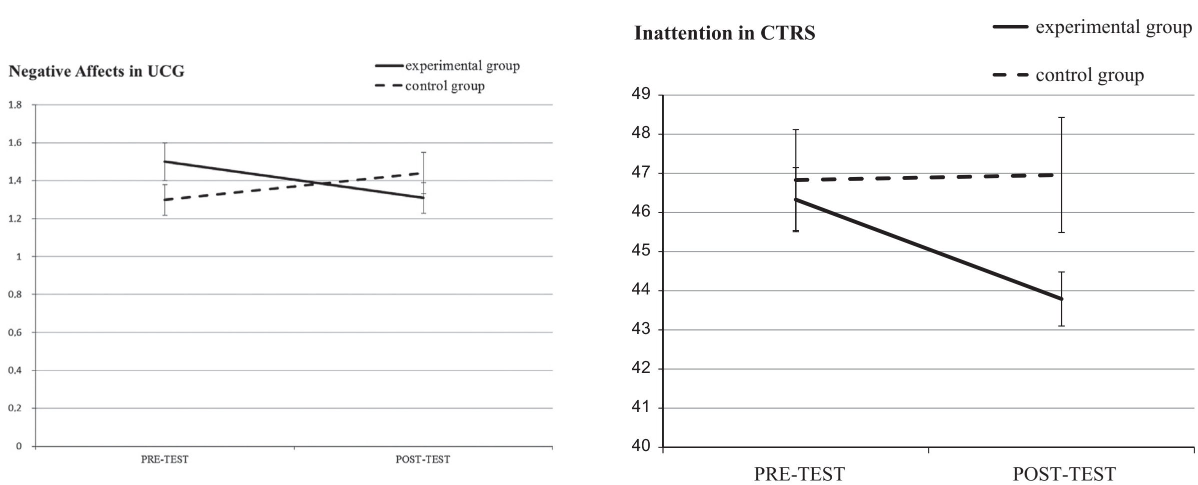

Fig. 2. Profile plots "PrePost * Group" for the UCG and CTRS.

include working memory tasks in their baseline (and they worked with school-aged children). In the present study, our baseline included measures of attention, working memory and flexibility. We found a significantly larger improvement in performance of attention tasks and working memory tasks in the experimental group than in the control group. This thus nicely shows the benefit of a very targeted intervention on other related EF, which again argues in favor of the large commonalities among all these EF dimensions, especially in young children (see [56]). However, our intervention did not have any effect on flexibility capacities. Our results are in line with those of Tamm et al. [33]: after a more general EF training, they found improvement in attention and working memory but no effect on flexibility. It is possible that this failure to observe any effect on flexibility is due to very low flexibility capacities in this preschool period and to the fact that it is still a function at the beginning of its emergence at this point. Working with somewhat older children (5- and 6-year-olds), Röthlisberger et al. [38] showed an improvement of flexibility capacities after their EF training. However, it should be mentioned that their training did include a significant number of flexibility exercises.

Third, we expected an impact on the behavioral side. Indeed, several studies have already shown significant correlation between EF and EB in preschool-age [24,25]. Longitudinal studies also showed that inhibition capacities in preschool-age could predict EB even 3 years later [21–23]. However, these studies are correlative in nature. One of the main purposes of this paper was thus to go further and examine whether manipulating EF could have an impact on EB. More specifically, our study aimed at increasing children inhibition capacity, as this is the EF most strongly related to EB. Currently, very few studies have tested this hypothesis. Noël et al. [28] showed an improvement in behavior after an inhibition training program, but they worked with a very small sample of school-aged children. In preschoolers, Halperin et al. [39] showed a decrease of ADHD symptoms as rated by parents after EF training, but this training did not focus only on EF, as it also included parent psychoeducation sessions and physical activities for the children. Moreover, beside the training sessions, children had also 30 to 45 min of daily homework exercises.

In this study, we therefore wanted to explore the behavioral impact of our intervention. To that aim, the child's behavior was assessed by both parents and teachers through questionnaires but also, and for the first time in this kind of study, by an observational paradigm (UCG). Indeed, in the case of EB disorders, it seems important to use multiple sources of information, since each of them provides unique information [57]. We wanted thus to take into account different types of assessments: those from purely objective cognitive tests as well as those made on the basis of questionnaires. On the other hand, much attention was paid to the parents' and teachers' assessments, since we know that a child often behaves differently at home or at school.

Results showed that our intervention led to an improvement in both direct and indirect measures. As regards the questionnaires, teachers reported a decrease of inattention symptoms in children after inhibition training but no change in the children from control group. Thus, although teachers were blind to the group to which the children belonged, they perceived changes in attention consistent with our hypothesis. On the other hand, parents did not report any significant changes in their child. It is possible that, as their formal involvement was limited to merely granting consent while the rest of the intervention took place at school, the parents were not really engaged with the intervention and not very attentive to possible changes in their child. Moreover, it should be noted that the level of difficulties reported by parents in pretest was already relatively low, which did not leave much possibility of improvement.

Importantly, our intervention also had effects that we could measure in our observational paradigm. Indeed, in the UCG that led to frustration, children from the experimental group showed a decrease in their negative affects (sighing, insults, etc), after the training, while this was not the case for children from the control group. It is also interesting to note that the intervention did not lead to any changes with respect to positive affect, which indeed should not be influenced by the level of inhibition of a child. Finally, we failed to find any effect on attention or agitation. However, as the child is seated at a computer, the situation is not really suitable for provoking agitation, and few attentional problems are observed, either.

In summary, to our knowledge, this is the first study which shows a significant decrease of EB in both direct and indirect measures in typically-developing preschoolers following a neuropsychological intervention, in addition of the effects on EF (which were already shown by Röthlisberger et al. [38] in typically-developing preschoolers and Tamm et al. [33] in young ADHD children).

We need also to point out the clinical interest of this research. Indeed, the ludic aspect of this intervention has the advantage of being highly motivating for children. In our sessions, it was very rare to observe children refusing to participate. The fact that the training was conducted in groups also has advantages: for example, that the children motivated each other, with the shier children being encouraged by the more active ones. Another innovative aspect of this research is the use of metacognition in our training. Recently, Espinet et al. [58] showed the benefit of reflection on EF capacities. In our study, metacognition has allowed the children to reflect on their own processes and understand which cognitive functions are involved in each proposed exercise. Moreover, it seems that it has promoted transfer, as after the training some children were, for example, talking about the "statue" when they had to stay calm in classroom.

Although this research has shown promising results, a number of limitations need to be considered. First, a larger number of participants would have given us more statistical power, which would have allowed us to observe significant results where we observe marginal effects and interactions. Second, literature shows that boys have more externalizing behaviors than girls [9,59,60]. However, in this study, girls outnumbered boys by a more than 2:1 ratio. Further research should look at whether the same effects are observed in a more male population. Third, although the interventions were fully planned with the list of specific exercises/games fixed for each training sessions, the difficulty level of the game was adapted to the children by the clinician in a quite subjective way as we did not have clear objective criteria such as x% of accuracy in a game to go from level of difficulty to another. Fourth, although our control group was not passive (they had handicraft sessions), it would have been better to have had an active control group that also took part in a cognitive training program but without any real challenges (e.g., playing at easy games below the participant's capacities). Finally, the aim of this research was to show the causal links between EF and EB, and that's why we focused exclusively on inhibition. As we were in a very controlled experimental setting, we worked exclusively with the child. However, in a real clinical setting, it might be interesting to also involve parents and even teachers in the intervention to have a bigger impact.

In this study, we showed that it is possible to act on EB even in preschool-aged children. Future studies should apply a similar design to different types of clinical populations, such as preschoolers who are referred by professionals for externalizing behavior disorder. Indeed, given our promising results, an early intervention in preschoolers with EB disorders could possibly decrease the likelihood of developing ADHD or other disorders a few years later. Finally, as we noted above, it could also be interesting in the future to include a parental training program in addition to the child intervention. As in Tamm et al.'s research [33], sensitizing and teaching the parents to train their child's EF in the context of everyday activities could increase the likelihood of making a greater impact with the intervention. If the parents understood cognitive functioning and could train it at home, that could also help to maintain the effect of the intervention in everyday life.

Ethical standards

The authors declare that this study has been approved by the ethics committee of the Psychological Research Institute of the Université Catholique de Louvain.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.tine.2015.02.001.

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