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Effects of a working memory training program in preschoolers with symptoms of attention-deficit/hyperactivity disorder

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Working memory (WM) has been defined as “a limited-capacity system allowing the temporary storage and manipulation of information necessary for such complex cognitive tasks as comprehension, learning, and reasoning” (Baddeley, 2000, p. 418). Baddeley’s (2000) theoretical model of WM distinguishes between a central controlled component (the “central executive”) and limited-capacity, short-term memory components. Research with children support the distinction between short-term memory tasks that involve the storage of information and WM tasks that demand attentional control (Alloway, Gathercole, & Pickering, 2006; Martinussen & Major, 2011). This distinction seems to be crucial in the case of children with attention-deficit/hyperactivity disorder (ADHD), who are weak in controlled WM, but not in short-term memory (e.g., Cornoldi, Giofrè, Calgaro, & Stupiggia, 2013). Finally Cornoldi (2007) have shown that the differentiation between passive (low controlled) and active (high controlled) WM processes may vary along a continuum also including intermediate cases.

ADHD is a developmental disorder characterized by inattention, impulsivity, and hyperactivity (American Psychiatric Association, 2013). Among the cognitive deficits identified in this disorder, WM impairment is particularly important (Kuntsi, Oosterlaan, & Stevenson, 2001; Mariani & Barkley, 1997; Rapport, Chung, Shore,

Denney, & Isaacs, 2000) because WM is associated with a broad set of academic skills, including mathematical problem solving, reading and language comprehension, and written expression (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Montgomery, Polunenko, & Marinellie, 2009; Swanson, Howard, & Sáez, 2007). WM is also associated with children’s ability to cope with requirements commonly encountered at school, such as following instructions (Gathercole, Durling, Evans, Jeffcock, & Stone, 2008). For example, Gathercole et al. (2008) reported a significant association between WM and the accuracy with which children were able to carry out instructions such as “Pick up the yellow ruler and put it in the black box.” WM difficulties are also associated with weaknesses in planning, organizing information, and monitoring school work (Alloway et al., 2009; Gathercole et al., 2008). Preschoolers with ADHD characteristics and children with problems in executive functions with poor WM may consequently be at risk of future weaknesses in learning academic skills.

Preschoolers are not frequently diagnosed with ADHD because at this age symptoms or delayed maturation could overlap with symptoms of ADHD and lead to incorrect diagnosis. Therefore, many studies have included children who exhibit symptoms and characteristics of ADHD, as reported by parents and teachers, but

who do not have a diagnosis. These studies that compare preschool-age children with symptoms to children without symptoms from the same cohort report impairment in WM (Mariani & Barkley, 1997; Re, De Franchis, & Cornoldi, 2010; Schoemaker et al., 2012; Sinzig, Vinzelberg, Evers, & Lehmkuhl, 2014), with particular association with weaknesses in control processes. In particular, Sonuga-Barke and colleagues (2002) examined a large sample of preschoolers with ADHD and found specific weaknesses in capacity for inhibition, planning, and WM. Also, Re and colleagues (2010), using a visuospatial WM task that required the selective recall of information, found that children with ADHD symptoms performed less well than controls, particularly in rates of intrusion errors (i.e., the recall of initially encoded information that needed to be suppressed during the task). In summary, the literature shows that WM is already impaired in preschoolers with ADHD symptoms, and that this ability is crucial to the children's development because it is essential for coping with academic and life demands in later years (Diamond, 2012). This means that WM could be the target of early interventions aiming to reduce the future negative consequences of a poor WM of children with ADHD, as also suggested by previous research showing the impact of early-onset ADHD symptoms (Sonuga-Barke, Thompson, Abikoff, Klein, & Brotman, 2006). Early intervention (Young & Amarasinghe, 2010) has also had positive consequences for the neurodevelopment of children with ADHD symptoms. Despite the potential benefits of early intervention on young children exhibiting ADHD symptoms, few intervention studies have been conducted on such children younger than six years of age. The role of WM has yet to be thoroughly investigated in this age group, whereas more work has been done with older children (Evans, Owens, & Bunford, 2013; Klingberg, Forssberg, & Westerberg, 2002).

In general, it seems important to devise intervention projects to support young children with ADHD symptoms, possibly involving not only the children themselves but also their schools and families (DuPaul & Kern, 2011; Sonuga-Barke, Daley, Thompson, Laver-Bradbury, & Weeks, 2001; Young & Amarasinghe, 2010). In fact, a meta-analysis (Rajwan, Chacko, & Moeller, 2012) found 29 intervention studies on young children, most of which concerned parent training. Only four studies considered a direct psychological intervention for the children, but they aimed mainly at teaching them skills for controlling their behavior, focusing on cognitive-behavioral strategies, or using contingency analyses and reinforcement techniques, without considering the associated neuropsychological problems in depth. Furthermore, only a few studies of preschool children involved intervention on executive

functions (EFs; Bergman Nutley et al., 2011; Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebbers, 2012). In particular, EF intervention programs for ADHD preschoolers were adopted in two studies, one by Halperin et al. (2012), the other by Re, Capodici, and Cornoldi (2015). In the first study, children and their parents took part in group sessions where they played games designed to develop inhibitory control, WM, attention, visuospatial abilities, planning, and motor skills. Parents were also prompted to play these games with their children for at least 30–45 min a day. Parents' and teachers' assessments of the severity of the children's ADHD symptoms dropped significantly from pre to post test. In the second study, a group training was provided at school to improve attentional control, WM, and impulsive behavior of 5-year-old children with ADHD symptoms. The children taking part in the intervention showed an improvement in their EFs, confirming the importance of early intervention for preschool-age children with ADHD symptoms.

To sum up, studies on the effects of cognitive intervention on young children's EFs have produced good results, but the effects of WM training on children with ADHD have yet to be studied in depth. The only study on this issue (Dongen-Boomsma, Vollebregt, Buitelaar, & Slaats-Willems, 2014) was implemented outside school, and has the limitation that requires the availability of a particular computerized program, and cannot be easily embedded in everyday school practices. More evidence is therefore needed on the effects of programs specifically targeting WM for preschoolers with ADHD symptoms and applicable as part of their everyday school activities, possibly in groups, and based on a protocol that makes any results repeatable (Rapport, Orban, Kofler, & Friedman, 2013). The preliminary evidence available on the effects of interventions on EFs with preschoolers with symptoms of ADHD (DuPaul & Kern, 2011; Halperin et al., 2012; Re et al., 2015) seems promising, showing long-term effects in preventing the disruptive behavioral problems (as referred in the follow-up thru a parents' questionnaire) associated with this condition (Kern et al., 2007; Washbrook, Propper, & Sayal, 2013), and it seems important to ascertain whether this is also true for the case of a training specifically focused on WM. The use of parental ratings has the limitation that it is a subjective measure, and parents could have incentive in the success of the program. The inclusion of both subjective rating and objective outcomes could help to have a better measure of the effectiveness of the trainings.

The present study was devoted to more systematically examining the effects of a WM training provided for groups of preschoolers as part of their school activities, and involving both children with ADHD symptoms and

typically developing (TD) children in interaction within each trained group. The inclusion within each group of both children with ADHD and typically developing children was due to the schools' adoption of an inclusion model where children with behavioral difficulties work together with children without problems, but had also the advantages of having activities deeply rooted in the school settings and of using children's classmates as positive models for ADHD children during the trained activities. Schools typically need interventions to be suitable for implementation during everyday activities, and to be of interest to all children in the class. The present study thus aimed to test the efficacy of an intervention embedded in the school setting and replicable by the schools themselves, although this carried the disadvantage of certain limitations and requirements imposed by the schools involved. The training focused on the active component of WM, which seems to be specifically impaired in children with ADHD (Cornoldi et al., 2013), using a published program and proposing group activities for promoting the children's active WM (Caponi, Clama, Re, & Cornoldi, 2009). We expected to see a specific effect of the training on active WM, and we also checked for transfer effects to other EFs, passive WM, short-term memory, and behavioral measures. The issue of transfer effects of WM treatments has been amply discussed in recent years. It has been argued that WM improvements cannot be generalized to other independent intellectual skills (e.g., Melby-Lervåg, Redick, & Hulme, 2016) or innate temperamental characteristics (Rappaport et al., 2013). An improvement might be seen in other types of memory or executive function, however, that share with active WM either the same short-term maintenance processes or the control processes. In the present study, this issue was investigated by testing the children before and after the training using not only a measure of active WM, but also passive WM and executive control measures. As the experimental design of our study focused on the children with ADHD symptoms, and TD were only involved at the request of the schools participating in the study, the focus of our analyses is on the former.

Method

Participants

The study involved 34 children attending their last year of kindergarten and exhibiting symptoms of ADHD, who resulted from a selection (see Figure 1) based on the consideration of 183 children belonging to schools including many at-risk children. It should be noted that these children had not been specifically diagnosed with ADHD—a condition still rarely diagnosed in Italy

at any age (Skounti, Philalithis, & Galanakis, 2007) and virtually never before six years old.

The authors identified symptoms of ADHD based on interviews and information collected from teachers using a validated rating scale, the IPDDAI [Identificazione Precoce del Disturbo da Deficit di Attenzione/iperattività per Insegnanti—(Early Identification of ADHD for Teachers); Re & Cornoldi, 2009], and from parents using another rating scale, the IPDDAG [Identificazione Precoce del Disturbo da Deficit di Attenzione/iperattività per Genitori (Early Identification of ADHD for Parents); Riello, Re, & Cornoldi, 2005]. The presence of each type of behavior was reported by teachers and parents using a 4-point Likert scale ranging from 0 to 3 (0 = *never*; 1 = *sometimes*; 2 = *often*; 3 = *always*). Ratings for the single items were summed in order to obtain, respectively, overall Inattention and Hyperactivity scores. As shown in Figure 1, at the beginning 183 children were assessed for eligibility, and then 53 were excluded for different reasons. After this first step, 130 children remained, and from this group we selected children with symptoms of ADHD (40 children) and matched peers without these characteristics (40 children); thereafter the children selected were allocated in the training or in the no-training condition.

The children with ADHD symptoms were randomly assigned to two conditions as follows: A total of 18 children (14 boys and 4 girls, $M_{age} = 65.88$ months, $SD = 3.81$) were involved in the experimental training (the training condition) while 16 (14 boys and 2 girls, $M_{age} = 65.88$ months, $SD = 3.77$) took part in their normal school activities (the no-training condition). The sizes of the groups were slightly different because, for organizational reasons, if one child in a class was assigned to a condition, eventually other children of the same class were assigned to the same condition. The two groups of children with ADHD symptoms completed their respective activities together with 40 TD children (IPDDAI total score below 3, i.e., >50th percentile) who were selected from the same classrooms as the children with ADHD symptoms and had similar age, schooling, sociocultural level, and general ability, but without any ADHD symptoms. In choosing the TD children to be involved in the study, we had to decide whether or not to maintain the same proportions of males and females as in the groups with ADHD symptoms (i.e., considerably more boys than girls). As the study design did not foresee comparisons between children with ADHD symptoms and TD children (but only between treated and untreated children with ADHD symptoms), after discussing this issue with the schools participating in the study, we opted to randomly select TD children in order to represent the

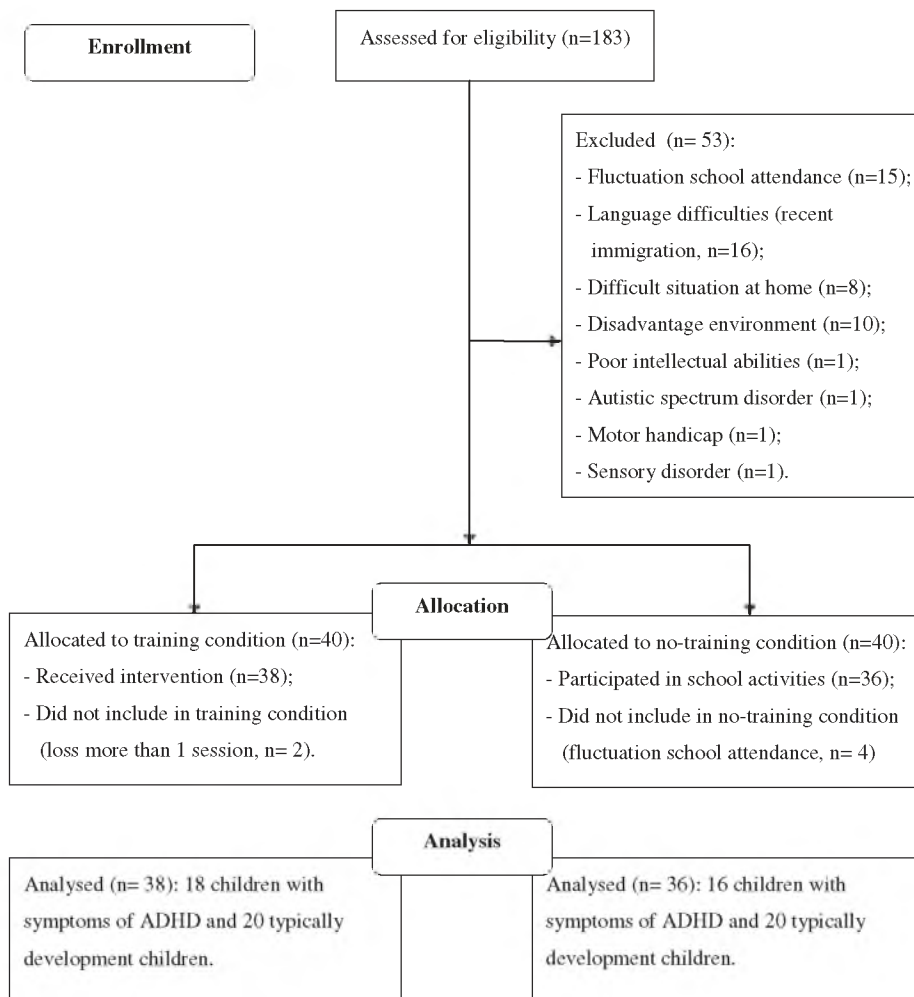


Figure 1. Procedure for selection and analysis of participants. ADHD = attention-deficit/hyperactivity disorder.

gender balance of a typical school class (see Re et al., 2015). Of the TD children selected, 20 (10 boys and 10 girls, $M_{\text{age}} = 66.55$ months, $SD = 3.63$) were randomly assigned to the training condition, and 20 (12 boys and 8 girls, $M_{\text{age}} = 66.63$ months, $SD = 4.72$) to the no-training condition. This study was conducted in accordance with the recommendations of the ethics committee of the University of Padua and was approved by the institutional committee.

Procedure

The authors identified symptoms of ADHD based on interviews and information collected from teachers using a validated rating scale, the IPDDAI (Re & Cornoldi, 2009) and from parents using another rating scale, the IPDDAG (Riello et al., 2005). The IPDDAI contains 14 items that refer to symptoms described in the *Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition* (DSM-5, American Psychiatric Association, 2013) and that are identified as the most predictive of ADHD in

children of preschool age (7 concerning inattention, 7 concerning hyperactivity/impulsivity) in the study by Re and Cornoldi (2009). As the full IPDDAI scale is not available in English, we have added its translation in an Appendix (see Appendix A). This version, used in the present study, includes additional items not referring to ADHD symptoms. Some additional items were included in the original version of the IPDDAI (Items 19, 20, 21, 22), and four items were specifically created for this study (Items 15, 16, 17, 18) in order to investigate the teachers' impression on children's WM functioning in everyday-life activities at school (e.g., "child has difficulty in remembering a short rhyme by heart"). The IPDDAI scale has been validated and standardized for the Italian population and appears to correlate closely with scores for ADHD obtained with the Conners' Teacher Rating Scale Revised (Nobile, Alberti, & Zuddas, 2007) for both Inattention ($r = .88$) and Hyperactivity ($r = .84$; Trevisi & Re, 2008). Though test-retest data are only available for the version for older children ($r = .80$), there is evidence showing the good predictive properties of the version for preschoolers.

In particular, Marcotto and colleagues (2002) found a positive correlation ($r = .56$) in a study correlating the IPDDAI scores awarded by kindergarten teachers with ADHD symptoms identified a year later by primary school teachers. Information collected with the scales was integrated with data from interviews with the teachers in order to examine whether the ADHD profile that emerged from the IPDDAI corresponded to an ADHD profile that emerged not only in classroom but also in other contexts.

The IPDDAG (an English version of the scale is presented in the Appendix of the paper by Re & Cornoldi, 2009) is parallel to the IPDDAI, and concerns the 14 symptoms found most representative of ADHD in children of preschool age and that showed the strongest discriminatory power in a preliminary study conducted with parents (Riello et al., 2005). It consists of 19 items: seven for inattention, seven for hyperactivity/impulsivity, and five for “risk factors” (poor cognitive abilities, languages difficulties, aggressive behaviors, emotional problems, and relational problems). The scale has a Cronbach’s alpha of .88 (Riello et al., 2005) and a medium test–retest reliability, $r = .59$, $p < .001$, for the total score (Marcotto et al., 2002).

We collected scores from the IPDDAI for all children, but unfortunately not all parents completed the IPDDAG questionnaire so that it was necessary to collect information on children’s behavior at home with informal interviews with teachers and parents. The ADHD group scored more than 9 (a cutoff suggested by Caponi et al., 2009, corresponding to the approximately 15th percentile) either on the Inattention or the Hyperactivity subscale of the IPDDAI or on both, and appeared to have symptoms of ADHD at home, judging from the parents’ ratings and parents’ and teachers’ responses. As a disadvantaged family, especially in the case of recently immigrated children who might have irregular school attendance, could find it difficult to implement the program, the group of children from a disadvantaged environment or difficult home situation were excluded based on interviews with teachers and the information obtained with the IPDDAI (see Appendix A, Items 19 and 21). Also, the few children with either weak intellectual abilities (as measured by the IPDDAI specific control item, see Appendix A, Item 20: We excluded children with the rating of 3) or other neurodevelopmental problems (in particular autistic spectrum disorder, sensory disorders, motor handicap, or other major neurological diseases) were excluded from the sample. Therefore all the children were Italian and had no physical, sensory, or neurological impairments, they spoke Italian fluently, and they had not grown up in a disadvantaged or problematic family. We also ascertained that the children were not receiving any other type of treatment including medication.

Tasks

After administering the teachers’ rating scale and before the training, all the children completed a set of tests. Following the Cornoldi (2007) classification, we administered one active WM measure (Span Backward; Bisiacchi, Cendron, Gugliotta, Tressoldi, & Vio, 2005), one high-demand active WM measure (Selective WM; Lanfranchi, Cornoldi, & Vianello, 2004; Re et al., 2010), one passive WM measure (Span Forward, Bisiacchi et al., 2005), and two EF measures in which previous research had found preschoolers with ADHD to be often impaired—that is, a controlled attention measure (the Walk–No Walk Test, Marzocchi, Re, & Cornoldi, 2010) and an impulsivity control measure (Matching Figures, MF-14; Marzocchi et al., 2010). Each test was preceded by instructions and practice trials. Testing was done individually by psychology post-graduate students and took about one hour for each child to complete. The tests were administered in the same order as follows: Span Forward, Span Backward, WM, Selective WM, Walk–No Walk, MF-14. Each test was only administered when the children appeared to have understood the nature of the task and had responded correctly in practice trials.

Forward and Backward Digit Span tests (FDS and BDS)

Similar to the classical digit span tasks (using the adaptation by Bisiacchi et al., 2005), in the Forward Digit Span (FDS) task children listened to a series of digits (e.g., 3, 8, 5) and were asked to repeat them immediately in the same order. If they did so successfully, they were given a longer list (e.g., 6, 8, 1, 2). In the Backward Digit Span (BDS) task, they were required to reverse the order of the numbers (e.g., for 5, 9, 6, they had to say 6, 9, 5). For the purposes of our study, we measured the number of series the children could correctly remember. The test–retest reliability for the FDS observed in a sample of 709 children from 59 to 140 months of age (Alloway et al., 2006) was .84, and for the BDS it was .64.

Selective Working Memory Test

This measure was obtained by combining two tasks that involve selecting and recalling target information, and inhibiting irrelevant information, while performing a concurrent task (hand clapping when a particular target was presented). The test used visuospatial and verbal material. The visuospatial material (Re et al., 2010) was based on a 4×4 matrix (17 cm \times 17 cm), divided into 16 cells, one of which was red. To make the task more attractive, a small plastic frog was shown moving around in the matrix. For each path taken by

the frog, the children had to remember its first position and clap their hands when the frog was in the red square. There were 10 trials of increasing difficulty, defined by the number of cells occupied by the frog (the length of the path) from a minimum of two to a maximum of six cells. There were two trials for each path length. The child was required to complete all trials of the test. A trial was completed correctly only if the child recalled the frog's first position and clapped their hands at the right time. Cronbach's alpha for this subtest is .84 (Lanfranchi, De Mori, Mammarella, Carretti, & Vianello, 2015). The verbal material (Lanfranchi et al., 2004) consisted of eight very concrete and familiar two-syllable words (i.e., the Italian two-syllable words corresponding to the English words house, mother, dog, cat, apple, grandma, ball, and sun). The experimenter presented the words verbally at a rate of 1 word per second. The task progressed to increasingly long lists, containing from two to five words. The children had to remember the first word on the list and to tap on the table when they heard the word "ball." The maximum scores on the Selective WM test was 18. Cronbach's alpha for this subtest is .85 (Lanfranchi et al., 2004).

Walk–No Walk test

The Walk–No Walk test (Marzocchi et al., 2010) is a paper-and-pencil test that assesses attentional control and inhibition of an ongoing response. It is derived from the "stop signal task" of Logan and Cowan (1984). The children had to follow a series of directions and inhibit an ongoing response when a particular event (an auditory signal) occurred. The test consists of two sheets of A4 paper on which 20 staircases (one for each trial) are drawn with a little frog on the first stair. The children were asked to start crossing out the stairs as if the frog was climbing them one by one each time they heard the GO signal, and to stop doing so every time heard the STOP signal. The STOP and GO signals were very similar but ended differently, so the children needed to wait until they had heard the whole sound before responding to a signal. The score corresponded to the number of trials completed correctly (maximum score = 20). The test–retest reliability is $r = .70$ (Marzocchi et al., 2010).

Matching Figures Test (MF-14)

The MF-14 test (Marzocchi et al., 2010) is derived from the Matching Familiar Figures Test (MFFT; Kagan, 1966) and assesses several executive functions, particularly impulsivity control. The test consists of 14 images of everyday objects, and comprises a target picture and six other similar pictures, only one of which is a duplicate of the target. The

child was told to identify the picture that was exactly the same as the target. The score for this test was the number of errors and could at the pure theoretical level of a child systematically selecting all the wrong responses for each item reach the error score of 70 (the range in a standardization sample of preschoolers was between 0 and 35). Although the test–retest reliability calculated in a series of studies and reported in the manual (Marzocchi et al., 2010) is only moderate (ranging between .49 and .60), the test has been validated and used successfully in a large number of studies (see Marzocchi et al., 2010).

Retest

A week after the children completed the training (see below), the teachers were invited to complete the IPDDAI scale again, the parents were asked to complete the IPDDAG questionnaire, and the children were administered the same measures as before the training, in the same order. Teachers were not naïve with respect to the condition, but the parents had not been explicitly informed about the study design. Furthermore experimenters who carried out the assessment (psychology postgraduate students) were blind to randomization (training vs. no training).

Training

The training was administered in 16 one-hour sessions distributed twice weekly over an 8-week period, in groups of 6–8 children (children were trained in a group, although many activities had to be carried out by each child individually within the group). The training involved activities presented in the manual published by Caponi and collaborators (2009; see also Re & Cornoldi, 2007), and was administered at school by one of the two class teachers supervised by trained psychologists in between routine school activities, whereas the other children remained with the other teacher. The training activities were divided into four main blocks (Appendix B presents the complete series of activities):

Block 1: The first two sessions introduced behavioral strategies for retaining and controlling information in WM. A dummy with his rhyming poem was presented at the start of each session to indicate the beginning of the specific training activity.

Block 2: The next six sessions trained selective WM, where the selection had to be based on a criterion indicated by the trainer. Games requiring pencil and paper or a motor activity were proposed.

Block 3: The next six sessions concerned selective WM in association with an interpolated task. Games

requiring pencil and paper or a motor activity were proposed.

Block 4: The last two sessions focused on the ability to update information in WM.

The training included no materials or procedures directly related to the pre and post measures.

Each session (the detailed description of a session is reported in Appendix C) was always arranged in the same way:

- (1) Metacognitive introduction: The trainer captured the children's attention and commented on the aim of the activity of the day.
- (2) Presentation of the cognitive demands: The trainer explained the activity for the day.
- (3) Instructions and preliminary practice with the activity of the day.
- (4) Organization of the activity: The trainer organized the activity and, in some cases, divided the children into smaller groups.
- (5) Practice with the activity: The trainer asked the children to complete the activity.
- (6) Promotion of strategic reflections: The trainer asked the children to comment on the activity and report strategies they had used or thought they could use. The trainer guided the children's descriptions of any such strategies.
- (7) Introspection and feedback: The trainer asked the children how well they thought they had done in the activity, gave them feedback, and discussed the reasons for any failures.

In the control condition, children were provided with an equivalent amount of time working on typical school activities, such as prereading and prewriting exercises. These activities were conducted by the other teacher of each class, who stimulated, as much as possible, the same type of interactions as those that were involved in the trained groups.

Fidelity of implementation

The authors of the present paper met every two weeks with the teachers involved in the study. During the training, the trainers kept a daily journal of the activities conducted at each session, which were examined by the experimenters and rated according to the degree of fidelity: low, medium, or high. In 90% of cases, the activities were rated as highly consistent with the training manual.

Data analysis

First, a comparison was drawn between the performance of the children with ADHD symptoms and the TD children in the pretest measures. Due to minor differences that emerged between the two groups of children with symptoms of ADHD in the initial measures, we decided to separately examine any changes in the performance of the two groups in the trained versus untrained condition (Student's *t* test with Bonferroni correction).

Audio recordings were also obtained in some cases, and sessions of observation and supervision were conducted for the control condition, considering the topics of each session.

Results

All children who were involved in the final groups, and whose data were analyzed, concluded the training with a maximum loss of one session. The two groups obtained similar scores on the IPDDAI rating scale (trained group: Inattention, $M = 9.46$, $SD = 3.70$, Hyperactivity, $M = 9.77$, $SD = 3.57$; control group: Inattention, $M = 9.56$, $SD = 4.30$, Hyperactivity, $M = 10.06$, $SD = 5.19$).

Table 1 shows the characteristics of the children with ADHD symptoms and the TD children on the behavioral and neuropsychological measures collected at pretest. Notice that for one measure (IPDDAG) it was not possible to collect information from all the parents but only for a relevant subgroup ($N = 28$ for children with symptoms of ADHD, $N = 26$ for TD children). As shown in Table 1, the differences between the performances of the ADHD and the TD groups in the pretest measures were significant for all measures except the FDS and Walk–No Walk tests. The finding for the FDS confirmed the hypothesis advanced by Cornoldi et al. (2013) that smart children with ADHD have more difficulty with active WM than with passive WM tasks. The Walk–No Walk task result was unexpected, however, and might be due to high variability in performances in this age due to task difficulty.

Due to minor differences that emerged between the trained and untrained groups of children with symptoms of ADHD in the initial measures (Table 2), we decided to separately examine any changes in the performance of the two groups (Student's *t*-test with Bonferroni correction). Table 2 shows that the trained group significantly improved in all the neuropsychological measures. The effect was greater, with a relevant (Cohen, 1988) effect size for the active WM (BDS), and the high-demand active WM measure (Selective Working Memory). A significant,

Table 1. Characteristics of the ADHD and the TD groups.

	ADHD symptoms (<i>N</i> = 34)	Typical development (<i>N</i> = 40)	<i>t</i> (72)
<i>Ratings</i>			
IPDDAI Inattention	9.51 (3.93)	1.99 (2.31)	9.80***
IPDDAI Hyperactivity	9.91 (4.34)	2.51 (2.43)	8.82***
IPDDAI WM	4.56 (3.50)	0.78 (1.51)	5.86***
IPDDAG Inattention	7.50 (4.25)	4.04 (3.01)	3.43**
IPDDAG Hyperactivity	9.82 (4.39)	5.50 (3.36)	4.04***
<i>Neuropsychological measures</i>			
FDS	3.56 (0.70)	3.60 (0.71)	0.25
BDS	1.15 (1.16)	1.83 (0.98)	2.69**
Selective Working Memory	7.65 (3.67)	10.73 (3.64)	3.61**
Walk–No Walk	9.39 (4.43)	9.75 (5.64)	0.29
MF-14	24.65 (7.22)	17.75 (7.30)	3.88***

Note. Means, with standard deviations in parentheses, and *t* test results of the comparison between the groups. ADHD = attention-deficit/hyperactivity disorder; TD = typically developing; IPDDAI = Rating Scale “Identificazione Precoce del Disturbo da Deficit di Attenzione/iperattività per Insegnanti” (Early Identification of ADHD for Teachers); IPDDAG = Rating Scale “Identificazione Precoce del Disturbo da Deficit di Attenzione/iperattività per Genitori” (Early Identification of ADHD for Parents); WM = Working Memory; FDS = Forward Digit Span; BDS = Backward Digit Span; MF = Matching Figures.

p* < .05. *p* < .01. ****p* < .001.

Table 2. Performance at pre and post test of children with symptoms of ADHD in the training and no-training conditions.

	Training (<i>N</i> = 18)		<i>t</i> (17)	<i>d</i>	No training (<i>N</i> = 16)		<i>t</i> (15)	<i>d</i>
	Pre test	Post test			Pre test	Post test		
<i>Teachers' ratings</i>								
IPDDAI Inattention	9.46 (3.70)	6.81 (3.89)	2.75	0.70	9.56 (4.30)	7.00 (4.70)	2.65	0.57
IPDDAI Hyperactivity	9.77 (3.57)	7.37 (3.65)	2.85	0.66	10.06 (5.19)	7.79 (5.18)	2.46	0.44
IPDDAI WM	4.49 (3.53)	1.66 (1.68)	4.43*	1.00	4.13 (3.52)	2.13 (2.03)	3.70*	0.70
IPDDAG Inattention	7.10 (5.69)	6.30 (3.64)	0.86	0.17	7.82 (2.82)	5.91 (2.77)	2.70	0.68
IPDDAG Hyperactivity	11.50 (4.95)	9.60 (4.90)	1.49	0.39	8.82 (3.84)	7.73 (3.61)	1.34	0.29
<i>Neuropsychological measures</i>								
FDS	4.78 (1.59)	6.17 (2.23)	3.13*	0.72	4.44 (1.86)	5.06 (1.69)	1.62	0.35
BDS	1.33 (1.70)	4.22 (1.68)	7.64*	1.70	2.50 (2.28)	3.00 (2.00)	0.82	0.23
Selective Working Memory	7.67 (2.57)	12.78 (3.32)	5.23*	1.70	7.63 (4.70)	10.00 (3.48)	2.46	0.57
Walk–No Walk	7.27 (3.86)	11.93 (3.61)	4.72*	1.25	11.38 (4.08)	13.13 (4.00)	1.68	0.43
MF-14	24.27 (7.18)	16.20 (5.12)	5.96 *	1.29	25.00 (7.62)	20.44 (6.39)	2.30	0.65

Note. Mean scores, with standard deviations in parentheses, and comparisons between the pre and the posttest measures (Student's *t* test and Cohen's *d*). ADHD = attention-deficit/hyperactivity disorder; IPDDAI = Rating Scale “Identificazione Precoce del Disturbo da Deficit di Attenzione/iperattività per Insegnanti” (Early Identification of ADHD for Teachers); IPDDAG = Rating Scale “Identificazione Precoce del Disturbo da Deficit di Attenzione/iperattività per Genitori” (Early Identification of ADHD for Parents); WM = Working Memory; FDS = Forward Digit Span; BDS = Backward Digit Span; MF = Matching Figures.

*Significant (alpha = .05) after Bonferroni's correction (*p* = .006).

albeit smaller, effect was seen for the FDS too, although passive WM was not the object of the treatment. A significant effect of the training emerged even in the tasks for measuring other EFs (attentional control and inhibition, Walk–No Walk, and impulsivity control, MF-14), which were outside the treatment goals. We observed small improvements in all measures in the control group as well, but they had low effect sizes and never reached statistical significance. Concerning the teachers' ratings of the children on attention and hyperactivity using the IPDDAI scale, we found a small but statistically not significant improvement in both groups. On the other hand, the ratings describing WM showed an improvement in both groups that, judging from the descriptive statistics and effect size (Table 2), was larger for the children who took part in the training. Similar results were found for parents' ratings using the IPDDAG scale, although the

significance of these results are diminished because not all parents, despite the fact that they in general seemed satisfied with the program, completed the questionnaire (*N* = 15 for the training condition and *N* = 13 for the no-training condition).

Based on the clinical significance criteria, the training improved children's performance compared with the non-trained children in all parameters, except for inattention of the IPPDAG rating scale, with large effect sizes, calculated with Cohen's *d* and interpreted according to Cohen (1988) recommendations, which ranged between 0.70 (for WM items of IPDDAI) and 1.70 (for BDS and Selective WM).

Conclusions

The main goal of this work was to examine the value of training of WM with children with symptoms of ADHD

in the extraordinarily sensitive period represented by their preschool years. For this purpose, we provided WM training for a group of 5-year-old children, adopting a metacognitive approach and aiming to improve the children's WM through playful activities that involved the need to maintain information and control it. The children with ADHD symptoms were randomly assigned to the training or the no-training condition given during normal school activities. At the request of the school, the children were trained together with other TD children to avoid isolating the children with ADHD symptoms.

Our results suggest that a WM training can be effective—although its effect was evident on our neuropsychological measures but not in the inattention and hyperactivity problems rated by teachers and parents (where the trained group improved slightly, but so did the control group). A part of the improvement seen in the children may be due to nonspecific factors, of course, such as practice with the tests, gains deriving from other general activities provided to the children during the same period, and their associated maturation over almost three months period (between pre and post test). The improvement seen in the neuropsychological measures was significant only in the trained group, however, which suggests that the training had a specific effect. In particular, the training that focused on active WM—on the ability to control information stored in WM—had a positive effect on the trained children and also concerned their passive WM, albeit to a lesser extent. This could be due to the effect of practice on the maintenance component of WM (also involved in active WM), but it may also be that the preschoolers benefitted from improved control abilities in short-term-memory tasks as, for 5-year-olds, short-term-memory tasks also require effort and control. In the trained group, a significant transfer effect was also observed for the EF measures, suggesting that training young children to control information stored in their WM may help them to improve their ability to control their cognitive activity in other tasks as well. In fact, the trained children also showed conspicuous improvements in the two tasks (FDS and Walk–No Walk) in which they had no particular difficulty by comparison with the TD children, suggesting that the training may not only attenuate their weaknesses, but reinforced the self-control (or reduced the impulsivity) of children with symptoms of ADHD.

Conversely, the teachers saw little improvement in the presence of ADHD symptoms, which decreased similarly in the two groups. It is worth emphasizing that it was necessary for the goals and method of our study to be shared with the teachers who rated the children, so they knew which children were in which group. This is a strength of the procedure, but also a weakness in terms of how the teachers' ratings should be interpreted. The

teacher's bias might have engendered an overly critical view of any symptom improvement in the trained group, however, which was rated on a par with the control group. There may have been a bias in the opposite direction, inducing the teachers to pay more attention to the symptoms of the children in the training group. Teachers reported a similar WM improvement in both groups, despite the fact that only the trained group significantly improved in the WM objective measures.

In our view, this study has important clinical and educational implications. First, it demonstrates the feasibility of administering WM training to preschool children who exhibit ADHD symptoms. Our training had the advantages of being easy to implement as part of the preschoolers' usual school activities, it was well received by children, teachers, and parents, and it produced specific effects on the children's WM. Because active WM is related to a number of school activities (e.g., comprehension, expressive writing, problem solving, mental calculation, etc.), we hypothesize that the benefits of improving WM could extend to various aspects of cognitive functioning and academic performance. In the present study, our trained group showed a significant improvement in EFs that had not been specifically trained—attentional control and impulsive response control. However, we were allowed to collect only a limited number of measures and could not assess far transfer effects, such as changes in school-related behaviors or longitudinal outcomes on primary academic abilities in the present study, so only future research will be able to shed more light on these aspects.

In particular, it has been suggested (Kern et al., 2007) that working with very young children can also have the advantage of helping to prevent any negative consequences for self-esteem and the emotional and motivational difficulties caused by having symptoms of ADHD, and may reduce the onset of oppositional or deviant behavior. Our training may contribute to improving self-esteem, but this aspect was not directly studied in the present research. In fact, the present study has other limitations including the small number of children trained, the modest involvement of their parents, and the absence of follow-up measures. Further research should also examine the issue of the specificity of the observed effects (as we could not exclude that social and motivational aspects of the training could affect the performance). Future studies should collect data on individual clinical profiles of the children, which might inform why some children improved while others did not. Further research examining the implications of the same type of WM training for preschoolers with other types of risk—for example, learning disabilities—may reveal WM weaknesses (Swanson et al., 2007). Even with these limitations, our findings show that great attention should be paid to the opportunities afforded by early cognitive

interventions for children with ADHD or who exhibit symptoms of this disorder. Even if a diagnosis of ADHD is difficult to discern in the preschool age, early identification and intervention could be very beneficial for the future of the children affected.

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Appendix A

IPDDAI, Early Identification of ADHD for Teachers

The present rating scale allows you to assess various aspects of your pupils' behavior. Your observations are very important for the identification of children who might have problems in attention and/or self-control. Please follow these instructions in the correct order:

1. Read the rating scale.
2. Observe the child.
3. Attempt to answer all questions independently, even if the child shows contradictory behaviors.

Use a 0 to 3 scale to indicate the intensity and frequency with which each of the following items characterizes the child: 0 = behavior never present, 1 = behavior sometimes present, 2 = behavior often present, 3 = behavior always present.

- (1) She or he often has difficulty sustaining attention in tasks or play activities.
- (2) If she or he hears a noise immediately, she or he leaves the task to see what happens.
- (3) She or he often starts tasks but quickly loses focus and is easily sidetracked.
- (4) She or he often blurts out an answers before a question has been completed.
- (5) She or he often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort.
- (6) She or he often leaves seat in situation when remaining seated is expected or activity requires it.

- (7) She or he often fails to give close attention to details when the task requires it or makes careless mistakes during activities (for example, given a figure as a model, cannot find the identical figures between multiple figures that differ in small details).
- (8) She or he often taps hands or feet or squirms in seat.
- (9) She or he when faced with a difficult task often becomes discouraged and gives up.
- (10) She or he often runs about or climbs in a situation where it is inappropriate.
- (11) She or he often tends not to think before doing something.
- (12) She or he often has difficulty waiting her or his turn and is impatient (e.g., while waiting in line and/or butts into conversations).
- (13) She or he often passes from one game to another, or from one activity to another, rather than engage on one task at a time.
- (14) She or he encounters difficulties in meeting the rules and to be collaborative playing with peers
- (15) She or he has difficulty learning short rhymes by heart.
- (16) She or he fails to repeat in her/his own words what has just been said.
- (17) He or she has difficulty remembering the information, examples, and orders given verbally earlier.
- (18) She or he fails to keep in mind several things at once (e.g., if you ask her/him to go and get three objects does not remember them all).
- (19) She or he comes from a disadvantaged family.
- (20) She or he has poor cognitive abilities.
- (21) She or he has a difficult situation at home.
- (22) She or he has emotional and relational problems.

Appendix B

Summary of tasks and sessions proposed to children.

	Tasks	Components investigated
Pre and post test	Teachers and parents: IPDDAI and IPDDAG and interviews. Children individual assessment: – Forward and Backward Digit Span tests; – Selective Working Memory Test; – Walk-No Walk Test; – Matching Figures Test	– high controlled active working memory; – short-term memory; – controlled attention; – impulsivity control
	Sessions	Main activities
Training	<i>First block</i> Session 1: Majestic Memorina Session 2: The Pizza Margherita <i>Second block</i> Session 3: The galipot game Session 4: The chessboard Session 6: Training your memory Session 7–8: Contrary Mary Session 9: The crystal cock Session 11–12: The scatterbrain bear <i>Third block</i> Session 13–14: What number was? Session 15–16: The memory game Session 17: The puzzle Session 18: The mysterious object <i>Fourth block</i> Session 19: The musicians from Bremen Session 20: The little backpack	Know and apply working memory control strategies and learn a rhyme about that; Remember selectively relevant information and inhibit irrelevant information Remember information selectively controlling the interference given by an interfering task Learn to update information in working memory

Appendix C

Example of a session

Number of session: 4

Area: control of visuospatial working memory

Objective: remember the position of only two (targets) of three children, moving in a chessboard (made of plastic rings on the floor)

Materials: 12 plastic rings from the gym, 2 hats, 1 tambourine

Time duration and place: 45 minutes, gym

Metacognitive introduction:

“Now we are going to play a game that will require all your attention, so you have to open your ears for listening and your eyes to see everything that is happening (strategies of Majestic Memorina). Furthermore you will need your memory. Are you ready?”

Choose two children and ask them to lay the rings on the floor to form a board of 3 lines of 4 rings each. Ask the children if they know what a chessboard is and for what it is used.

Presentation of the cognitive demands:

Inform the children about the cognitive demands and the expected results.

“With this game you will improve your ability to follow the displacement of some of your classmates in a special chessboard (the trainer points to the rings on the floor). You need to pay attention, follow like a radar the displacement of a plane, update the changing of the place in memory, and always know the right position.”

Instructions and preliminary practice with the activity of the day:

“Now each of three children stay in a different position inside a ring in the special chessboard. I’m putting a hat on two of them. Pay attention to your classmates wearing the hat. Then I’ll beat the tambourine. Each time I beat, your mates will move to a different ring, as my sound corresponds to one displacement. When I say STOP, everybody will stay in the position for 3 seconds and then exit the chessboard and come to me. And all the others what do you have to do? You have to look carefully at the position of children with hats and try to remember where they were placed when I said STOP. Then I will give the hats to two of you, and you have to place them in the last position of your mates with hats.” (Be sure that all children have understood the instructions asking someone to explain to others. Administer two practice trials and remember the strategies.)

Organization of the activity:

Teacher controls that the materials are available and that children are ready and have understood instructions. The teacher reminds the children that they have to pay attention to hats and their positions, follow the hats without being distracted by others, and finally, remember the position of one child with a hat and remember the position of the other one in relationship with the first one.

Practice with the activity:

The children complete the activity. They play the game until they have assumed all the different roles.

Promotion of strategic reflections:

The teacher asks the children to verbalize how they maintained in mind the correct positions of the children with hats. If some children succeed and others do not, they try to explain why. The teacher controls that all children have achieved the objectives, i.e., they have:

- identified the final position of the two children with hats;
- controlled their memory allowing time to give the final answer;
- described the strategies used and why they eventually did not succeed.

If needed (if one or more children have not succeeded) the teacher lets them try another time.

Introspection and feedback:

Complete the present metacognitive schedule selecting one picture connected with one of the three sentences read by teacher. For example:

“To remember the final positions of children with hats:

- (1) I looked to all children and gave the answer I thought could be right;
- (2) I followed the two children with hats and I finally remembered the position of only one of them;
- (3) I followed the two children with hats and I memorized the positions of both of them.”

The session was concluded by giving positive reinforcement to children, such as, “you have done a really good job,” asking if someone used the suggestions of Majestic Memorina, and inviting children to reward themselves by telling themselves “I did not give answers in a hurry,” “I used my memory in a correct way,” “I did my best.”