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ADHD Subtype Differences in Reinforcement Sensitivity and Visuospatial Working Memory

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Both cognitive and motivational deficits are thought to give rise to the problems in the combined (ADHD-C) and inattentive subtype (ADHD-I) of attention-deficit hyperactivity disorder (ADHD). In both subtypes one of the most prominent cognitive weaknesses appears to be in visuospatial working memory (WM), which is composed of short-term memory (STM) and a central executive (CE). In children with ADHD-C, both STM and the CE seem impaired, and together with motivational impairments, give rise to their deficits in visuospatial WM. In children with ADHD-I, no studies investigated these WM components and their interplay with motivational impairments. Effects of a standard (feedback only) and a high level of reinforcement (feedback + 10 euros) on visuospatial WM-, STM-, and CE performance were examined in 27 children with ADHD-I (restrictive-subtype), 70 children with ADHD-C, and 40 typically developing controls (aged 9–12). In both ADHD-subtypes CE and WM performance was worse than in controls. STM performance of children with ADHD-I was, in contrast to that of children with ADHD-C, not different from controls. STM and WM performance was worse in ADHD-C than in ADHD-I, whereas CE-related performance did not differ. High reinforcement improved STM and WM performance in both subtypes but not in controls. This improvement was equally pronounced in both subtypes. High reinforcement did not improve CE-related performance. Both subtypes have equally pronounced motivational deficits, which have detrimental effects on their visuospatial STM and WM performance. In contrast to children with ADHD-C, children with ADHD-I seem unimpaired on visuospatial STM; only an impaired CE and motivational impairments give rise to their deficits in visuospatial WM.

The two most prevalent and valid diagnostic subtypes of attention-deficit hyperactivity disorder (ADHD) are the predominantly inattentive subtype (ADHD-I) and the combined subtype (ADHD-C; Gomez, Harvey, Quick, Scharer, & Harris, 1999; Willcutt et al., 2012; Wolraich, Hannah, Baumgaertel, & Feurer, 1998). Although ADHD-C and ADHD-I are characterized by distinct patterns of symptomatic behavior, associated features and demographics (e.g., see Milich, Balentine, & Lynam, 2001), it is unclear whether these two subtypes have different underlying deficits.

Theories of ADHD state that both cognitive and motivational deficits give rise to the problems children with ADHD-C and ADHD-I experience in daily life

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(e.g., Barkley, 2006; Diamond, 2005; Sonuga-Barke, 2003, 2011). Motivational deficits in ADHD are thought to be characterized by an abnormal sensitivity to reinforcement (e.g., Haenlein & Caul, 1987; Sergeant, Oosterlaan, & Van der Meere, 1999) and by a disposition to be more easily underaroused compared to typically developing (TD) children (Diamond, 2005). Meta-analyses investigating cognitive deficits in ADHD (e.g., Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005; Willcutt et al., 2012) demonstrate that, compared to TD children, both children with ADHD-C and children with ADHD-I are strongly impaired on tasks measuring *working memory* (especially *visuospatial* working memory).

Working memory is described as the ability to maintain, control, and manipulate goal-relevant information. Working memory enables skills like reasoning, planning, problem solving, and goal-directed behavior (Baddeley, 2007; Conway, Jarrold, Kane, Miyake, & Towse, 2007; Martinussen et al., 2005). According to Baddeley (2007, 2010) working memory is a multicomponent system consisting of two storage subsystems and a *central executive*. The storage subsystems—phonological and visuospatial *short-term memory*—are dedicated to the short-term storage of modality (phonological or visuospatial) specific information. The central executive is a mental control system with limited attentional resources that is responsible for supervising, controlling, and manipulating information in these short-term memory systems. When the context (e.g., in daily life or during task performance) asks for changes in attentional demands, the central executive intervenes, for example, by dividing, focusing or switching attention to relevant information or by reorganizing/updating information.

Studies investigating working memory components in children with ADHD-C find that both their short-term memory and central executive are impaired (e.g., Alderson, Rapport, Hudec, Sarver, & Kofler, 2010; Dovis, Van der Oord, Wiers, & Prins, 2013; Rapport et al., 2008; Rhodes, Park, Seth, & Coghill, 2012; but also see Karatekin, 2004). However, less is known about the level of impairment of these working memory components in children with ADHD-I. A recent meta-analysis by Willcutt et al. (2012) concluded that children with ADHD-I are impaired on tasks assessing short-term memory and on tasks assessing working memory. However, because working memory performance is inherently composed of both short-term memory and central executive performance, deficits in either or both these components may account for the impairments found on the working memory measures in children with ADHD-I (Nigg, 2006). Furthermore, close inspection of the studies examining short-term memory in Willcutt et al. showed that only a minority (30%) of these studies found a significant difference between the short-term memory performance of children with ADHD-I and TD children. Outcomes of the working memory studies were more consistent; about 70% found a significant difference between children with ADHD-I and TD children (e.g., Willcutt et al., 2012; see also Alloway, Elliott, & Place, 2010; Cockcroft, 2011; Marusiak & Janzen, 2005).[1] These findings seem in line with a theoretical appraisal by Diamond (2005), who proposed that children with ADHD-I have a deficient central executive but are not impaired in short-term memory related skills such as encoding or retrieving items from memory. Moreover, Diamond suggested that children with ADHD-I have motivational deficits, which may interact with their cognitive functioning: Children with ADHD-I would be more easily underaroused than TD children and therefore, under average (mostly low-stimulating) test conditions, have difficulty maintaining sufficient motivation during task performance. Under average test conditions this motivational deficit could then result in unstable cognitive performances in children with ADHD-I and might thereby explain the inconsistencies found in the short-term memory and working memory studies investigated by Willcutt et al. (2012).

Although no studies directly investigate this proposed interaction between motivational processes and working memory, short-term memory, and central executive performance in children with ADHD-I, evidence suggests motivational deficits in children with ADHD-C (for reviews, see Luman, Oosterlaan, & Sergeant, 2005; Luman, Tripp, & Scheres, 2010), and an interaction of these motivational deficits with their short-term memory and working memory performance: Dovis et al. (2013) demonstrated that not only cognitive deficits but also motivational deficits give rise to the poor visuospatial short-term memory and working memory performance of children with ADHD-C (see also Dovis, Van der Oord, Wiers, & Prins, 2012; Strand et al., 2012). There is even evidence suggesting that the components of working memory may be differentially influenced by motivational deficits. For example, Dovis et al. (2013) found that additional incentives (€10) only improved the short-term memory performance but not the central executive-related performance of children with ADHD-C.

To date, few studies have investigated motivational processes and their interaction with cognitive functioning in children with ADHD-I at all (see Carlson, Booth, Shin, & Canu, 2002; Derefinko et al., 2008; Huang-Pollock, Mikami, Pfiffner, & McBurnett, 2007). Although the results of these studies are not entirely consistent, they appear broadly in line with Diamond's (2005) notion that children with ADHD-I have motivational deficits that

[1]For comparison, 50% of the studies that were examined in Willcutt et al. (2012) found a difference between ADHD-C and controls on short-term memory, and 80% found a difference on working memory.

may interact with their cognitive functioning. For instance, Carlson et al. (2002) used parent, teacher, and self-report ratings to investigate motivational styles in children with ADHD-I, ADHD-C, and TD children and found motivational impairments that are likely to interact with cognitive functioning (e.g., a stronger preference for easy work, less persistence) in both ADHD subtypes. Furthermore, Huang-Pollock et al. (2007) found that children with ADHD-I showed a stronger decline in performance on an inhibition task when incentives decreased over time than TD children or children with ADHD-C. In contrast, Derefinko et al. (2008) found no effect of incentives on the slow and variable inhibitory functioning of children with ADHD-I. However, Derefinko et al. concluded that the incentives (trial-based monetary incentives, adding up to a total of about $1) may not have been sufficient to arouse the children with ADHD-I to improve their performance. Although we are not aware of studies that compare the effects of different amounts of incentives on cognitive performance in children with ADHD-I (but see Scheres, Tontsch, Thoeny, & Kaczkurkin, 2010), this conclusion of Derefinko et al. seems in line with a recent study by Dovis et al. (2012), which found that, compared to feedback only (FO), only relatively high incentives (e.g., feedback + 10 euros), but not incentives of a lower value (feedback + 1 euro), could improve and stabilize the persistence of performance over time in children with ADHD-C.

In sum, although it is suggested that children with ADHD-I have no impairment in short-term memory (in contrast to children with ADHD-C) but have a deficient central executive and motivational deficits that interact with cognitive functioning (Diamond, 2005), to date no studies have investigated this interplay between motivational processes and the short-term memory, central executive, or working memory performance in children with ADHD-I.

Finally, in the benchmark review of Milich et al. (2001), it is suggested that using the standard *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev. [*DSM-IV–TR*]; American Psychiatric Association, 2000) cutoff of six hyperactivity/impulsivity symptoms to distinguish between ADHD-I and ADHD-C compromises the discriminant validity of these subtypes (as individuals with subthreshold ADHD-C may also be classified as having ADHD-I). Therefore, Milich et al. proposed that only ADHD-I with few (e.g., three or less) hyperactivity/impulsivity symptoms may be qualitatively distinct from ADHD-C. Several studies have investigated this and, in contrast to studies including the broader subtype of ADHD-I, reported potential success differentiating this restrictive inattentive subgroup from ADHD-C on several neuropsychological measures (see Willcutt et al., 2012). However, no studies have investigated this for working memory and its interplay with motivational processes.

In this study, we investigated (a) whether the visuospatial[2] working memory, short-term memory, and central executive performance of children with ADHD-I (restrictive-subtype) is different from that of TD children and children with ADHD-C, and (b) whether these differences result from motivational deficits. We investigated this by comparing the effects of a standard and a relatively high amount of reinforcement on the visuospatial short-term memory and visuospatial working memory (short-term memory + central executive) performance of children with ADHD-I, ADHD-C, and TD children (controls), using a mixed factorial design.

We compared the mean performance of these groups of children on the working memory version and short-term memory version of the Chessboard task (Dovis et al., 2013). We presented these visuospatial task versions in two reinforcement conditions: an FO condition and a condition with feedback and a large monetary incentive (€10). This 10 euros condition was previously found to optimize task performance in children with ADHD-C (Dovis et al., 2012). Performance related to the central executive was examined by the individual difference between mean short-term memory performance and mean working memory performance.[3]

We expected that (a) with FO, the short-term memory, central executive, and working memory performance of children with ADHD-I and ADHD-C would be worse than that of controls (Diamond, 2005; Dovis et al., 2013; Willcutt et al., 2012); (b) the performance differences between children with ADHD (of both subtypes) and controls, on both the short-term memory and working memory task, would be smaller in the 10 euros condition than in the FO condition, suggesting an abnormal sensitivity to reinforcement in both ADHD subtypes (e.g., Carlson et al., 2002; Sonuga-Barke, 2003); (c) in the 10 euros condition, only the short-term memory performance of children with ADHD-C, but not of children with ADHD-I, would be worse than that of controls, suggesting no short-term memory deficit in

[2]Meta-analytic findings suggest that children with ADHD show much more impairment on tasks that measure *visuospatial* working memory or short-term memory than on tasks measuring *phonological* working memory or short-term memory (Martinussen et al., 2005; Nigg, 2006; Willcutt et al., 2005). Therefore, in this study we focus on visuospatial working memory and its components.

[3]Operationalizing central executive performance by using the difference between working memory performance and short-term memory performance is based upon the theorem of Engle, Tuholski, Laughlin, and Conway (1999)—which is consistent with other influential working memory models like those of Cowan (1995) and Baddeley and Hitch (1974)—that the working memory system consists of the contents of short-term memory plus the central executive. According to Engle et al., “working memory capacity = short-term memory capacity + central executive + the error of measurement” (p. 313).

ADHD-I (Diamond, 2005); and (d) that in the 10 euros condition, the working memory, and central executive performance of both children with ADHD-I and ADHD-C would be worse than that of controls (e.g., Diamond, 2005; Dovis et al., 2013).

METHOD

Participants

There were 137 children aged 9 to 12 years who participated: 27 children with ADHD-I, 70 children with ADHD-C, and 40 TD children. Children with ADHD were recruited from outpatient mental-healthcare centers, TD children through elementary schools. This study was conducted in the Netherlands, within a predominantly urban type of community. The ADHD-C and TD samples are subsamples from the ADHD-C and TD samples previously examined by Dovis et al. (2013) matched on age with the ADHD-I sample (i.e., because the ADHD-I sample in the present study was aged 9–12 years, only 9- to 12-year-old children were included in this study, whereas Dovis et al. included 8- to 12-year-olds).

Inclusion Criteria

For all groups. (a) An IQ score of 80 or more established by the short version of the Dutch Wechsler Intelligence Scale for Children (Kort et al., 2002). Two subtests, Vocabulary and Block Design, were administered to estimate Full Scale IQ. This composite score has satisfactory reliability and correlates highly with Full Scale IQ (Sattler, 2001). (b) Absence of any neurological disorder, sensory (color blindness, vision), or motor impairment as stated by the parents. (c) Not taking any medication other than methylphenidate.

For the ADHD-C group. (a) A prior *DSM-IV-TR* (American Psychiatric Association, 2000) diagnosis of ADHD combined-type and absence of any autism spectrum disorder (ASD) according to a child psychologist or psychiatrist. (b) A score within the clinical range (95–100th percentile) on the ADHD scales of both the parent and teacher version of the Disruptive Behavior Disorder Rating Scale (DBDRS; Pelham, Gnagy, Greenslade, & Milich, 1992; Dutch translation: Oosterlaan, Scheres, Antrop, Roeyers, & Sergeant, 2000). The DBDRS contains four *DSM–IV–TR* scales: Inattention, Hyperactivity/Impulsivity, Oppositional Defiant Disorder (ODD), and Conduct Disorder (CD). Adequate psychometric properties are reported (Oosterlaan et al., 2000). (c) Meeting criteria for ADHD combined-type on the ADHD section of the Diagnostic Interview Schedule for Children, Parent Version (PDISC-IV; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). The PDISC-IV is a structured diagnostic interview based on the *DSM–IV–TR*, with adequate psychometric properties. (d) Absence of CD based on the CD sections of the PDISC-IV.[4]

For the ADHD-I group. (a) A prior *DSM–IV–TR* diagnosis of ADHD inattentive-type and absence of any ASD according to a child psychologist or psychiatrist. (b) A score within the clinical range on the Inattention scale and a score below the clinical range on the Hyperactivity/Impulsivity scale of both the parent and teacher version of the DBDRS. (c) To ensure that the ADHD-I group did not include any children with subthreshold ADHD-C, we followed recommendations made in the benchmark review of Milich et al. (2001; also see Barkley, 2006; Diamond, 2005): children in the ADHD-I group not only had to meet criteria for ADHD inattentive-type on the ADHD section of the PDISC-IV but also had to have less than four hyperactivity/impulsivity symptoms. (d) No CD based on the CD sections of the PDISC-IV.

The control group. (a) A score within the normal range (<80th percentile) on all scales of both the parent and teacher version of the DBDRS. (b) Absence of a prior *DSM–IV–TR* diagnosis of ASD or any other psychiatric disorder as stated by the parents.

Group differences in demographics and characteristics are listed in Table 1. Eight children in the ADHD-I group (30%) and 47 children in the ADHD-C group (67%) were taking Methylphenidate[5] but discontinued medication at least 24 hr before the test session, allowing a complete washout (Greenhill, 1998).

Procedure

The study was approved by the faculty's Institutional Review Board. After informed parental consent, parents and teacher completed the DBDRS. If DBDRS inclusion criteria were met, participants were invited to one 100-min test session. During this session's 1st hour, the two reinforcement conditions (FO and 10 euros), each containing the working memory and short-term memory version of the chessboard task, were administered, intermitted by a 5-min break. Thereafter, the Wechsler

[4]CD was excluded because it seems independently associated with motivational impairment (possibly caused by different underlying processes than in ADHD; Rubia et al., 2009).

[5]This relative difference between the ADHD groups in medication use was significant, $\chi^2(1) = 11.168$, $p = .001$. However, including medication use as a covariate in analyses where the ADHD groups were compared did not change the results.

TABLE 1
Group Demographics

	Group							
	ADHD-I[a]		*ADHD-C*[b]		*TD Children*[c]			
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	F/χ^2	*Group Comparison*[d]
Gender (M : F)	18 : 9	—	56 : 14	—	20 : 20	—	10.7	I = C, TD; C ≠ TD
Age (years)	11.1	1.1	10.8	1.1	10.7	0.8	1.4	*ns* ($p = .251$)
FSIQ	106	10.5	100	11.6	109	13.3	7.7	I = C, TD; C < TD
DBDRS Parent								
Inattention	19.0	4.5	21.5	3.9	2.5	2.6	349.4	TD < I < C
Hyperactivity/Impulsivity	7.0	3.4	20.8	4.4	2.4	2.5	356.8	TD < I < C
ODD	5.5	4.4	12.1	5.4	1.8	2.1	71.6	TD < I < C
CD	0.9	1.4	2.7	2.4	0.1	0.3	27.9	TD = I; C > TD, I
DBDRS Teacher								
Inattention	15.4	5.0	17.2	4.9	1.7	1.8	170.7	TD < I, C; I = C
Hyperactivity/Impulsivity	2.9	2.4	15.3	5.5	1.0	1.5	174.7	TD = I; C > TD, I
ODD	2.0	2.8	8.10	5.9	0.6	1.0	37.4	TD = I; C > TD, I
CD	0.3	0.8	1.7	2.1	0.1	0.2	17.2	TD = I; C > TD, I
Weekly Spendable Income (Euros)	2.3	1.6	2.8	2.8	2.0	1.2	1.8	*ns* ($p = .177$)
Dyscalculia (Yes : No)	0 : 27	—	0 : 70	—	0 : 40	—	—	—
Dyslexia (Yes : No)	0 : 27	—	5 : 65	—	2 : 38	—	2.1	*ns* ($p = .358$)

Note: ADHD-I = attention-deficit hyperactivity disorder inattentive subtype; ADHD-C = attention-deficit hyperactivity disorder combined subtype; TD = typically developing; M: F = male: female; FSIQ = Full Scale IQ; DBDRS = Disruptive Behavior Disorder Rating Scale; ODD = oppositional defiant disorder; CD = conduct disorder.

[a] $n = 27$.

[b] $n = 70$.

[c] $n = 40$.

[d] Multivariate analyses of variance were performed. If the group-effect was significant ($p < .05$), post hoc Tukey tests were performed to clarify the differences (for all significant differences p values were <.02). Nominal data were investigated using chi-square tests.

Intelligence Scale for Children subtests were administered. In parallel, parents of children with ADHD were interviewed with the PDISC-IV. If the child met the inclusion criteria (s)he was included in the data set.

To control for order effects, the order of administration of the reinforcement conditions and the task versions (short-term memory and working memory) were counterbalanced separately within groups (resulting in $2 \times 2 \times 2 = 8$ orders of presentation).[6] No information about the reinforcement conditions was provided before the test session (e.g., to avoid expectations of receiving money). Children and their families were not compensated for participating in this study over and above the €10 from the high-reinforcement condition. Children with ADHD were tested at their mental-healthcare center (both ADHD samples were recruited and tested in the same outpatient mental-healthcare centers, using the same testing procedures and experimenters), TD children at their school. Testing took place between 9 a.m. and 5 p.m. Test rooms were quiet, and views from windows were blocked. Specific reinforcement instructions (e.g., "If you perform well enough on this task you will get these 10 euros") were given to the child at the start of each reinforcement condition (for complete instructions, see description of the reinforcement conditions). During testing an experimenter was present, sitting behind the child pretending to read a book.

The Chessboard Task: Working Memory and Short-Term Memory

The working memory version of the Chessboard task (Dovis et al., 2012, 2013) is a visuospatial working memory performance measure that is based on two working memory tasks: the Corsi Block Tapping Task (Corsi, 1972) and the subtest Letter-Number Sequencing from the Wechsler Adult Intelligence Scale (Wechsler, 1997). The working memory task taps the ability to both maintain and reorganize visuospatial information that is relevant for the task at hand (see Figure 1). To ensure that every presented sequence of stimuli (see Figure 1)

[6] Orders of presentation used in counterbalancing:

1. FO: STM > WM	>	10 euros: STM > WM
2. 10 euros: STM > WM	>	FO: STM > WM
3. FO: WM > STM	>	10 euros: WM > STM
4. 10 euros: WM > STM	>	FO: WM > STM
5. FO: STM > WM	>	10 euros: WM > STM
6. 10 euros: STM > WM	>	FO: WM > STM
7. FO: WM > STM	>	10 euros: STM > WM
8. 10 euros: WM > STM	>	FO: STM > WM

Note: STM = short-term memory; WM = working memory; FO = feedback only.

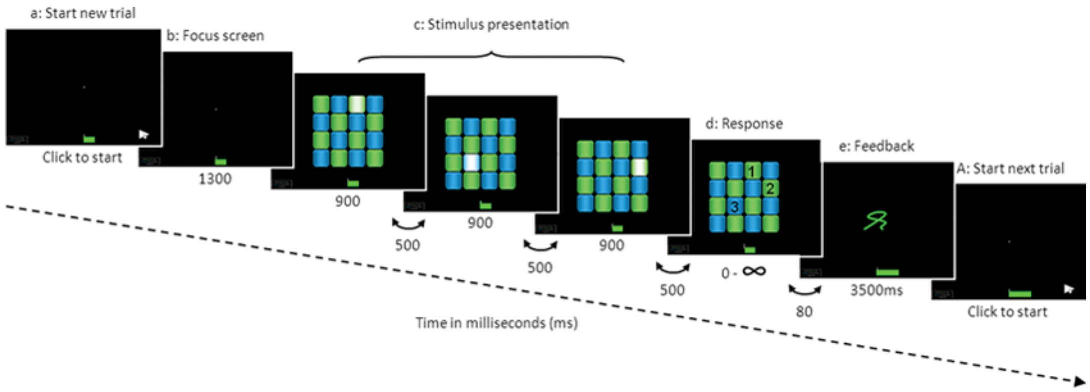

FIGURE 1 A trial on the working memory version of the Chessboard task. *Note*: (a) To start a trial the arrowhead-button in the bottom-right corner of the screen has to be clicked. (b) Then the focus screen (a black screen with a little white cross) is presented. (c) Subsequently, a sequence of stimuli (squares that light up) is presented one by one on a 4×4 grid with green and blue squares ordered in a chessboard formation. Each stimulus lights up for 900 ms and is followed by an inter-stimulus interval of 500 ms. (d) After the stimulus-sequence is presented the participant responds by mouse-clicking on the squares. To respond correctly, the presented stimuli have to be reproduced in a reorganized way: The green stimuli have to be reproduced before the blue stimuli; both in the same order as presented (the numbers in Picture d show an example of a correct reorganization). (e) After a response feedback is presented. (A) After feedback-presentation, the participant can start the next trial by clicking on the arrowhead button (from Dovis et al., 2013).

has to be reorganized (and the central executive is tapped), the order of stimuli presentation is random with the restriction that in every sequence at least one blue stimulus is presented before the last green stimulus.

The short-term memory version of the Chessboard task (Dovis et al., 2013) is a visuospatial short-term memory performance measure tapping the ability to maintain visuospatial information relevant for the task at hand. The short-term memory version is a short-term memory analogue of the working memory task: The stimuli have to be reproduced in the same way as on the working memory task; green stimuli have to be reproduced before the blue stimuli (see Figure 1). However, in contrast to the working memory task, on each trial of the short-term memory task all the green stimuli are presented before the blue stimuli. Therefore, none of the presented sequences on the short-term memory task have to be reorganized (and only the storage component is tapped; for a more detailed description, see Dovis et al., 2013).

The difficulty level of both tasks is adaptive; after two consecutive correct or incorrect reproductions, the sequence is increased or shortened by one stimulus. Minimal sequence length is two stimuli, and there is no maximum sequence length. Because the difficulty level adapts to individual performance, the amount of positive and negative feedback is approximately the same (55% reward, 45% response-cost) for each child and in both task versions and both reinforcement conditions. To ensure optimal attention/vigilance of the participant during each trial, the tasks are self-paced (the participant has to click to start a trial), and each stimulus is presented with the same short tone. To prevent the use of strategies (e.g., positioning the mouse cursor on one of the squares in the sequence to unburden WM) the mouse cursor is not visible during sequence presentation. Each task consists of approximately five practice trials followed by 30 experimental trials and takes about 10 min to complete (for more details, see Dovis et al., 2013).

Reinforcement Conditions

Each participant completed both reinforcement conditions, and each reinforcement condition contained both the short-term memory and working memory task. In the FO condition, children were instructed to do their best and respond as accurately as possible. In the 10 euros condition, children were told that they could earn €10 if they performed well enough on the task. In both reinforcement conditions, participants received immediate visual and auditory feedback and could monitor their overall performance by means of a "performance bar" (for a detailed description, see Dovis et al., 2013, or Appendix A).

Dependent Measures

On both task versions, the first 12 trials are required to reach the child's optimal difficulty level and were therefore excluded from analysis (Dovis et al., 2012, 2013). Thus, performance on each task version was measured by the mean sequence length of the last 18 trials.

Data Analysis

The ADHD-C and TD group differed significantly on IQ and gender (see Table 1); therefore, these variables were used as covariates when these groups were compared. As there is debate whether IQ should be covaried when comparing ADHD and TD children (Dennis et al., 2009), all analyses were also conducted without covarying for IQ. If these results differed, we describe both analyses (with and without covarying for IQ); otherwise we describe only the most conservative findings (including IQ and gender as covariates).

Because the ADHD groups differed significantly on parent-rated Inattention on the DBDRS (Table 1) and showed a trend toward a significant difference on IQ ($p = .062$), we included these variables as covariates when these two groups were compared. The ADHD groups also differed on ODD and CD on the DBDRS. However, children with ADHD-I generally show fewer symptoms of ODD and CD than children with ADHD-C (e.g., Eiraldi, Power, & Nezu, 1997; Willcutt, Pennington, Chhabildas, Friedman, & Alexander, 1999), and covarying for ODD and CD may therefore take away characteristic subtype differences. Hence, if results with and without covarying for ODD and CD differed, we describe both analyses; otherwise, we only describe the findings without these covariates.

Dependent measures were subjected to repeated measures analyses of covariance (ANCOVAs) with group (ADHD-I/ADHD-C/control) as between-subject factor and reinforcement condition (FO vs. 10 euros) and task version (short-term memory vs. working memory) as within-subject factors. Because repeated measures were used, covariates were entered after mean centering (see Delaney & Maxwell, 1981). In AN(C)OVAs *the central executive performance* was investigated using the factor "task version" (i.e., the difference in performance between the short-term memory and the working memory task). In additional within-group analysis (e.g., paired *t* tests) central executive performance was calculated for each reinforcement condition by extracting the working memory performance from the short-term memory performance for each participant.[7] Partial eta-squared effect sizes are reported for all analyses: $\eta_p^2 = .01$ is regarded a small effect size, .06 a medium effect size, and .14 a large effect size (Kittler, Menard, & Phillips, 2007).

RESULTS

Counterbalancing

The three groups did not differ in the relative number of times that each counterbalancing-order was presented, $\chi^2(14) = 2.032$, $p = 1.000$. Also, including counterbalancing order as a covariate did not change the results.

Mean Performance

A $3 \times 2 \times 2$ (Group $\times$ Reinforcement Condition $\times$ Task Version) repeated measures ANCOVA with mean sequence length as dependent variable (covaried for IQ and gender), showed a main effect of reinforcement condition, where performance was better with 10 euros than with FO, $F(2, 132) = 25.18$, $p < .001$, $\eta_p^2 = .16$ (see Figure 2); task version, where performance was better on the short-term memory task than on the working memory task, $F(2, 132) = 5.11$, $p = .025$, $\eta_p^2 = .04$; and group, $F(2, 132) = 12.35$, $p < .001$, $\eta_p^2 = .16$. Both the Reinforcement Condition $\times$ Group interaction, $F(2, 132) = 4.29$, $p = .016$, $\eta_p^2 = .06$, and Task Version $\times$ Group interaction, $F(2, 132) = 4.76$, $p = .010$, $\eta_p^2 = .07$, were significant. Other interactions were nonsignificant. Next, to obtain more insight into the two-way interactions, follow-up repeated measures AN(C)OVAs were performed.

ADHD-I versus TD Children

A $2 \times 2 \times 2$ (Group $\times$ Reinforcement Condition $\times$ Task Version) repeated measures ANOVA with mean sequence length as dependent variable, showed a main effect of Reinforcement condition, where performance was better with 10 euros than with FO, $F(1, 65) = 10.35$, $p = .002$, $\eta_p^2 = .14$ (see Figure 2), no main effect of task version, $F(1, 65) = 1.32$, $p = .255$, $\eta_p^2 = .02$, and a main group effect, where performance was worse in children with ADHD-I than in TD children,

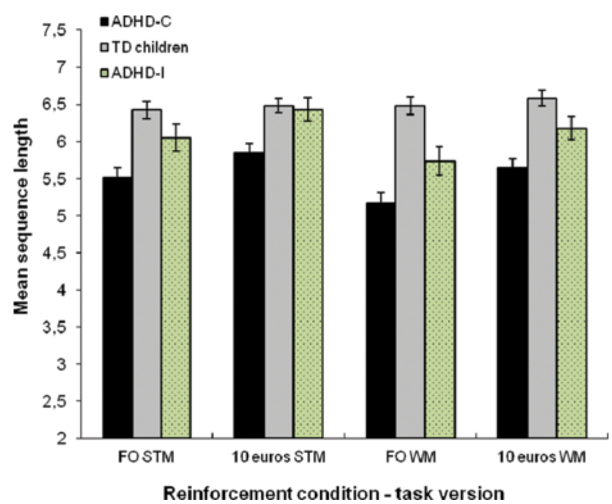

FIGURE 2 Mean performance of children with attention-deficit hyperactivity disorder combined subtype (ADHD-C), attention-deficit hyperactivity disorder inattentive subtype (ADHD-I), and typically developing (TD) children on the visual-spatial short-term memory (STM) and working memory (WM) task in the feedback-only (FO) and 10 euros condition.

[7]CE FO = STM FO – WM FO; CE 10 euros = STM 10 euros – WM 10 euros (CE = central executive performance, WM = mean score on working memory task; STM = mean score on short-term memory task; FO = feedback-only condition; 10 euros = 10 euros condition).

$F(1, 65) = 4.67$, $p = .034$, $\eta_p^2 = .07$. The Reinforcement Condition × Group interaction was significant: The performance difference between the ADHD-I and TD group was smaller with 10 euros than with FO, $F(1, 65) = 4.13$, $p = .046$, $\eta_p^2 = .06$ (suggesting motivational deficits in children with ADHD-I). The Task Version × Group interaction was also significant: The difference in performance between the short-term memory and the working memory task (i.e.,. the effect of increased taxation of the central executive) was more pronounced in children with ADHD-I than in TD children, $F(1, 65) = 8.05$, $p = .006$, $\eta_p^2 = .11$ (suggesting less central executive capacity in children with ADHD-I). We found no significant Reinforcement Condition × Task Version interaction, $F(1, 65) = 0.18$, $p = .669$, $\eta_p^2 = .003$, and no significant Reinforcement Condition × Task Version × Group interaction, suggesting that the effect of reinforcement on the difference in performance between the short-term memory and the working memory task (i.e., central executive related performance) was not more pronounced in children with ADHD-I than in control children, $F(1, 65) = 0.04$, $p = .836$, $\eta_p^2 = .001$.

ADHD-C versus TD Children

The effects of a 2 × 2 × 2 (Group × Reinforcement Condition × Task Version) repeated measures ANCOVA with mean sequence length as dependent variable (covaried for IQ and gender) were comparable to the effects found in the ADHD-I versus TD analyses (see earlier): There was a main effect of reinforcement condition, $F(1, 106) = 14.63$, $p < .001$, $\eta_p^2 = .12$; no main effect of task version, $F(1, 106) = 1.35$, $p = .248$, $\eta_p^2 = .01$; and a main group effect, $F(1, 106) = 22.94$, $p < .001$, $\eta_p^2 = .18$ (see Figure 2). The Reinforcement Condition × Group Interaction, $F(1, 106) = 8.48$, $p = .004$, $\eta_p^2 = .07$, and Task Version × Group interaction, $F(1, 106) = 7.14$, $p = .009$, $\eta_p^2 = .06$, were significant. The Reinforcement Condition × Task Version interaction, $F(1, 106) = 0.48$, $p = .488$, $\eta_p^2 = .005$, and Reinforcement Condition × Task Version × Group interaction, $F(1, 106) = 1.18$, $p = .280$, $\eta_p^2 = .01$, were nonsignificant.

ADHD-I versus ADHD-C

A 2 × 2 × 2 (Group × Reinforcement Condition × Task Version) repeated measures ANCOVA with mean sequence length as dependent variable (covaried for IQ and parent-rated Inattention),[8] showed a main effect of reinforcement condition, where performance was better with 10 euros than with FO, $F(1, 93) = 29.71$, $p < .001$, $\eta_p^2 = .24$; task version, where performance was better on the short-term memory task than on the working memory task, $F(1, 93) = 9.83$, $p = .002$, $\eta_p^2 = .10$; and group were performance was better in children with ADHD-I than in children with ADHD-C, $F(1, 93) = 5.93$, $p = .017$, $\eta_p^2 = .06$ (see Figure 2). The Reinforcement Condition × Group interaction was nonsignificant, $F(1, 93) = 0.21$, $p = .886$, $\eta_p^2 < .001$, suggesting that the ADHD groups have comparable reactions to reinforcement. The Task Version × Group interaction was also nonsignificant, $F(1, 93) = 0.45$, $p = .503$, $\eta_p^2 = .005$, suggesting that the ADHD groups have comparable central executive capacity. Other interactions were also nonsignificant.

Within-Group Analyses per Task Version

For each task version (short-term memory and working memory) and for the difference in performance between the task versions (i.e., the central executive), differences between the reinforcement conditions within each group were tested with additional paired t tests (p values were not corrected for multiple comparisons).

Working Memory Task Version

Compared to FO, 10 euros significantly improved performance of children with ADHD-I, $t(26) = -2.98$, $p = .006$, and ADHD-C, $t(69) = -4.84$, $p < .001$, but not of controls, $t(39) = -0.80$, $p = .429$ (see Figure 2).

Short-Term Memory Task Version

Compared to FO, 10 euros significantly improved performance of children with ADHD-I, $t(26) = -2.47$, $p = .020$, and ADHD-C, $t(69) = -3.77$, $p < .001$, but not of controls, $t(39) = -0.82$, $p = .415$.

Central Executive Performance

Compared to FO, 10 euros did not significantly improve performance of children with ADHD-I, $t(26) = 0.45$, $p = .655$; ADHD-C, $t(69) = 1.22$, $p = .228$; or that of controls, $t(39) = 0.17$, $p = .870$.

Between-Group Comparison per Task Version

To investigate whether the reinforcement effect that was found for the short-term memory and working memory task version could "normalize" the performance of children with ADHD to the level of TD children and to compare differences in task performance between the subtypes, the performance differences between the groups on these task versions were tested for both reinforcement conditions using MAN(C)OVAs (covaried

[8]With covarying for ODD and CD, the pattern of the results was the same. Further, these covariables did not significantly interact with task version, and only parent-rated CD interacted significantly with reinforcement condition, $F(1, 91) = 5.23$, $p = .025$, $\eta_p^2 = .05$. Covarying for IQ or Inattention also did not change the pattern of the results.

for IQ and gender when ADHD-C was compared to controls; covaried for IQ and parent-rated inattention when the ADHD groups were compared).[9]

Working Memory Task Version

Children with ADHD-I performed worse than controls in both the FO condition, $F(1, 65) = 10.12$, $p = .002$, $\eta_p^2 = .14$, and the 10 euros condition, $F(1, 65) = 4.05$, $p = .048$, $\eta_p^2 = .06$. Children with ADHD-C performed worse than controls in both the FO condition, $F(1, 106) = 31.53$, $p < .001$, $\eta_p^2 = .23$, and the 10 euros condition, $F(1, 106) = 15.40$, $p < .001$, $\eta_p^2 = .13$. Children with ADHD-I performed better than children with ADHD-C in both the FO condition, $F(1, 93) = 5.06$, $p = .027$, $\eta_p^2 = .05$, and the 10 euros condition, $F(1, 93) = 4.85$, $p = .030$, $\eta_p^2 = .05$.

Short-Term Memory Task Version

Children with ADHD-I did not perform different from controls in the FO condition, $F(1, 65) = 2.663$, $p = .108$, $\eta_p^2 = .04$, and the 10 euros condition, $F(1, 65) = 0.10$, $p = .757$, $\eta_p^2 = .001$ (see Figure 2). Children with ADHD-C performed worse than controls in both the FO condition, $F(1, 106) = 11.30$, $p = .001$, $\eta_p^2 = .10$, and the 10 euros condition, $F(1, 106) = 5.05$, $p = .027$, $\eta_p^2 = .05$. Children with ADHD-I did not perform different from children with ADHD-C in the FO condition, $F(1, 93) = 2.04$, $p = .157$, $\eta_p^2 = .02$, but performed better in the 10 euros condition, $F(1, 93) = 5.71$, $p = .019$, $\eta_p^2 = .06$.

DISCUSSION

This study examined the impact of a standard (FO) and a high level (feedback + 10 euros) of reinforcement on the visuospatial working memory; visuospatial short-term memory; and the central executive performance of children with ADHD-I, ADHD-C, and TD children. In the FO condition, the working memory and the central executive performance of children with ADHD-I and ADHD-C was worse than that of TD children. However, the short-term memory performance of children with ADHD-I was, in contrast to that of children with ADHD-C, not significantly different from TD children. High reinforcement improved the short-term memory and the working memory performance in both ADHD groups, but not in TD children. Nonetheless, high reinforcement did not "normalize" the short-term memory and working memory performance of children with ADHD-C or the working memory performance of children with ADHD-I. High reinforcement appeared not to improve central executive-related performance. In both reinforcement conditions, children with ADHD-I showed better working memory performance than children with ADHD-C (although effect sizes were small). Short-term memory performance was also better in children with ADHD-I than in children with ADHD-C, but only in the high reinforcement condition (where the effect size was medium). There was no difference between the ADHD groups in central executive-related performance. Reinforcement effects were also equally pronounced in both ADHD subtypes.

These findings suggest that both children with ADHD-I and ADHD-C have motivational deficits that have a detrimental effect on their visuospatial short-term memory and working memory performance. These motivational deficits seem to be equally pronounced in both ADHD subtypes. Furthermore, in contrast to children with ADHD-C, children with ADHD-I seem not impaired on visuospatial short-term memory; only impaired central executive and motivational deficits seem to give rise to the visuospatial working memory deficits in children with this subtype. The central executive seems equally impaired in both subtypes.

The high level of reinforcement improved performance in both ADHD subtypes but not in controls. This may suggest that for TD children, providing FO constituted sufficient reinforcement to reach optimal performance, whereas this was clearly not the case for children with ADHD-I and ADHD-C.[10] This is in line with theories suggesting that children with ADHD are characterized by an abnormal sensitivity to reinforcement (ADHD-C; e.g., Haenlein & Caul, 1987; Sergeant et al., 1999) and by a disposition to be more easily underaroused compared to TD children (ADHD-I; Diamond, 2005), and contradicts theories stating that motivational abnormalities characterize the combined subtype only (e.g., Sagvolden, Johansen, Aase, & Russell, 2005). Further, our findings support the notion that motivational deficits interact with cognitive functioning in children with ADHD-I (Carlson et al., 2002; Diamond, 2005; Huang-Pollock et al., 2007) and ADHD-C (e.g., Dovis et al., 2012, 2013; Sonuga-Barke, 2011; Strand

[9]Covarying did not change the pattern of the results.

[10]Here we assume that the TD group was highly motivated in both reinforcement conditions, whereas the ADHD groups were highly motivated only in the 10 euros condition. This assumption is substantiated by participants' reports: After both reinforcement conditions were administered, children were asked what they thought of the task with FO and of the task with 10 euros. In line with our assumption, children in both ADHD groups were less positive about the task in the FO condition (40% reported that the FO task was fun) than about the task in 10 euros condition (80% reported that the 10 euros task was fun), whereas TD children were positive about the tasks in both reinforcement conditions (72.5% reported that the FO task was fun, and 80% reported that the 10 euros task was fun; for more details, see Appendix B).

et al., 2012). However, although high reinforcement improved cognitive performance more in the ADHD groups than in the TD group, the central executive and working memory performance of children with ADHD-I and the short-term memory, central executive, and working memory performance of children with ADHD-C were still impaired compared to that of TD children (i.e., high reinforcement did not "normalize" performance). These findings suggest that motivational factors can only partially explain the working-memory-related impairments in these subtypes. This, and the fact that we found no significant short-term memory deficit in children with ADHD-I, supports Diamond's suggestion that children with ADHD-I have deficient working memory, which is mainly characterized by central executive impairments, not by impairments in short-term memory (Diamond, 2005). In addition, our findings are consistent with previous studies showing that children with ADHD-C are impaired on both components of working memory (e.g., Alderson et al., 2010; Dovis et al., 2013; Rapport et al., 2008; Rhodes et al., 2012).

Our study shows equally pronounced motivational deficits in both ADHD subtypes. However, because two reinforcement conditions were compared that differ widely in intensity (FO vs. high reward), subtle differences between the motivational deficits may not have been detected. For example, Huang-Pollock et al. (2007) compared the effects of two reward conditions (2 vs. 10 points) and found that children with ADHD-I showed a stronger decline of performance than children with ADHD-C only when rewards decreased over time. In future studies it would be interesting to compare the effects of more diverse reinforcement intensities between the ADHD subtypes.

Visuospatial short-term memory performance differentiated between the ADHD subtypes only in the high reinforcement condition (medium effect size), not in the standard reinforcement condition. This is consistent with previous studies that were unable to find subtype differences in visuospatial short-term memory performance when standard reinforcement was used (for an overview, see Willcutt et al., 2012; but also see Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2005) and promotes the use of additional incentives in such studies to optimize cognitive differentiation between ADHD-I and ADHD-C.

A strength of our study is the stringently selected ADHD-I group. Following recommendations made in the benchmark review of Milich et al. (2001), children in the ADHD-I group were required to have less than four symptoms of hyperactivity/impulsivity. According to Milich et al., the standard cutoff of six hyperactivity/impulsivity symptoms compromises the discriminant validity of ADHD-I and ADHD-C (because individuals with subthreshold ADHD-C may also be included in the ADHD-I group). The significance of this suggestion may be underlined by the difference between our findings and the findings of studies using the standard cutoff: In contrast to our findings, the latter did not find significant differences between ADHD-I and ADHD-C on visuospatial working memory performance (see Willcutt et al., 2012; but note that the effect size for the difference in our study was small).

In contrast to children with ADHD-I and ADHD-C, control children showed no performance differences between the short-term memory task and the working memory task. Thus, in TD children a task that needs additional central executive involvement does not seem to require the additional processing space that is needed to obtain an observable impact on their task performance. The finding that the additional central executive load of the working memory task was only high enough to impact the task-performance of children in the ADHD groups, but not of control children, does not affect our conclusion that both children with ADHD-I and ADHD-C seem to have less central executive capacity compared to TD children. However, it does suggest that the difference in central executive capacity between children with ADHD and TD children might be even larger than was found in the present study. In future research, it would be interesting to include an additional working memory task with a higher central executive load to assess the precise extent of the central executive deficits in the subtypes of ADHD. Further, the fact that central executive performance in this study was represented by the difference in performance between the short-term memory task and the working memory task, and not by a task itself, may have impacted the reliability of our central-executive-related results. Therefore, future studies should preferably use a task that measures central executive performance by itself, for example, by using a task that keeps the short-term memory load constant while the taxation of the central executive is varied.

As in previous studies (Dovis et al., 2012, 2013), we found no significant effect of incentives on the performance of TD children. Although this does not affect our conclusion that both children with ADHD-I and ADHD-C have an abnormal sensitivity to reinforcement, it does make it impossible to assess the precise extent of their motivational abnormalities. To obtain an incentive effect in TD children, the baseline condition should probably not contain any immediate reinforcement. This is supported by Strand et al. (2012), who found an incentive effect in both children with ADHD-C and TD children (although the incentive effect was still more pronounced in children with ADHD-C) when they compared a no-feedback condition to a monetary incentive condition. Therefore, in future studies it would be interesting to include a no-feedback condition to be able to make a more precise assessment of the motivational abnormalities in the ADHD subtypes.

Another possible limitation of our study may have been the difference between the ADHD groups on parent-rated inattention on the DBDRS (see Table 1). However, in ADHD group-comparisons, this inattention score did not significantly interact with our within-subject factors (reinforcement condition and task version), and covarying for this inattention score did not change the results. This suggests that our outcomes were not confounded by this difference in inattention. In addition, the ADHD groups did not differ on teacher-rated inattention on the DBDRS.

The sample size of the ADHD-I group was relatively small ($n = 27$), which suggests that the null finding between children with ADHD-I and TD children on the short-term memory task should be interpreted with some caution (due to the possibility of type II error). Nonetheless, at least in the high reinforcement condition (which is most important because findings are less confounded by motivational deficits than in the FO condition) the p value was high ($p = .757$) and the effect size was very low ($\eta_p^2 = .001$), suggesting that a replication study using a larger sample is not likely to find a different result.

Although all children discontinued their ADHD medication at least 24 hr before testing (allowing a complete washout), there was a difference between the ADHD groups in prior medication use: medication use was more common among children with ADHD-C. However, because evidence suggests that performance on working memory measures is not influenced by the chronic use of ADHD medication (Coghill, Rhodes, & Matthews, 2007; Rhodes, Coghill, & Matthews, 2004), and because including medication use as a covariate did not change our results, we assume that the outcome of this study was not confounded by the difference in medication use.

Although our findings suggest that both children with ADHD-I and ADHD-C require extra reinforcement to optimize performance, we did not specifically investigate what causes this aberrant reaction to standard levels of reinforcement. For instance, additional reinforcement might compensate for deficits in arousal (i.e., the phasic physiological responses to input; Pribram & McGuinness, 1975) in children with ADHD (Diamond, 2005), but effects are indirect via the effort pool (Sergeant et al., 1999) and may therefore also compensate deficits in activation (the tonic physiological readiness to respond; Pribram & McGuinness, 1975). Future research should investigate this further (for inspiration, see Loo et al., 2009).

This study primarily focused on differences *between* ADHD subtypes. However, there is also evidence for heterogeneity *within* these subtypes (e.g., Fair, Bathula, Nikolas, & Nigg, 2012; Sonuga-Barke, Bitsakou, & Thompson, 2010). Therefore, future research should (also) look beyond traditional ADHD subtypes and specify the subgroups within these subtypes based on their cognitive (i.e., working memory, short-term memory, and central executive) and/or motivational impairments.

Clinical Implications

Professionals, parents, and teachers should be aware that in situations that are motivating enough for TD children, both children with ADHD-I and ADHD-C are likely to perform suboptimally on short-term memory and working-memory-related tasks and functioning (e.g., keeping information in mind, reasoning, problem solving). To prevent suboptimal performance and to enable utilization and assessment of their full cognitive abilities, children of both ADHD subtypes should be motivated as strongly as possible. Moreover, to further reduce working-memory-related problems in children with ADHD-I, it is especially important to minimize demands on their central executive: Due to a lack of attentional resources in their central executive, normal increases in attentional demands (i.e., "working" with stored information) will presumably strongly impair utilization of the information that is stored in their probably intact short-term memory. These considerations support the use of token/reward systems and techniques to unburden working memory in evidence-based ADHD interventions such as behavioral parent and teacher training (Pelham & Fabiano, 2008). Finally, our results imply that interventions such as working memory training, of which there is debate as to whether mainly short-term memory is trained (e.g., Shipstead, Redick, & Engle, 2012), should focus more on training the central executive, especially in children with ADHD-I.

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APPENDIX A

1. Detailed description of the reinforcement conditions (from Dovis et al., 2013).

Reinforcement conditions

There are two reinforcement conditions (Feedback-only and 10 euros) that both contain the short-term memory version and the working memory version of the Chessboard task. Both reinforcement conditions and the task versions within these conditions are presented in counterbalanced order. For both reinforcement conditions the procedure is as follows: after a brief introduction the task version (short-term memory or working memory) that will be presented first in the reinforcement condition starts with a practice block (of about 5 trials). Next, the first instruction of the reinforcement condition is presented (*see* Appendix A & C). After this instruction, 30 trials of the first task version are presented. After the first task version is completed, the second task version in the reinforcement condition is introduced and practiced. Next, the second instruction of the reinforcement condition is presented (*see* Appendix B & D). After this second instruction 30 trials of the second task version are presented. When the second task version of the first presented reinforcement condition is completed (and after a 5 minute break), the remaining reinforcement condition (also containing the two task versions) is administered using the same procedure.

In *the feedback-only (FO) condition*, children are instructed to do their best and respond as accurately as possible. In the second instruction they are also told that when the task is finished, a purple screen will appear (*see* Appendix A & B).

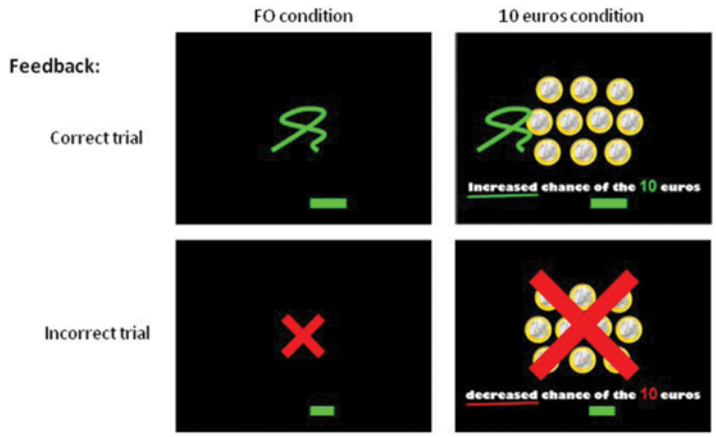

FIGURE A Visual feedback in the Feedback-Only (FO) and 10 euros condition (from Dovis et al., 2013).

In *the 10 euros condition*, children are told that they can earn 10 euros if they perform well enough on the task. Then, the euro coins which can be earned are shown and placed in sight above the laptop keyboard (the coins remain there during both task versions). The child is told that the euros can only be gained if (s)he makes enough correct responses and not too many incorrect responses. The child is told that the computer randomly decides the required amount of correct and incorrect responses. Further, the child is told that if enough correct responses are made, the task will immediately end with a green screen indicating that the euros are won, but that if too many incorrect responses are made, the task will immediately end with a red screen indicating that the euros are lost (for verbatim instructions see Appendix C & D). Although participants are made to believe that their immediate performance directly influences their chance of winning the euros and that every incorrect or correct response can immediately end the task with a red or a green screen, in reality the reinforcement condition always ends with the green screen and after both task versions are completed; thus, participants always received the money.

In both the FO condition and the 10 euros condition, participants received immediate visual and auditory feedback and could monitor their overall performance by means of a ‘performance bar’. The performance bar was always visible at the bottom of the screen. In the FO and the 10 euros condition, feedback consisted of the same sounds (a positive guitar sound for correct trials and a negative buzzer sound for incorrect trials), the same distance of adaptation of the performance bar, and of comparable pictures (*see* Figure A).

APPENDIX B

1. Details of reinforcement condition evaluation by participants.

Procedure

After both reinforcement conditions were administered, the child was asked two questions (translated from Dutch): “What did you think of the task with the curl and the cross?”(i.e., FO task), and “What did you think of the task with the 10 euros?”. Possible answers were: (1) fun, (2) not fun/not tedious, (3) tedious.

Results

In both ADHD groups children were less positive about the task in the FO condition than about the task in the 10 euros condition (see Figure B), whereas typically-developing children were positive about both reinforcement conditions.

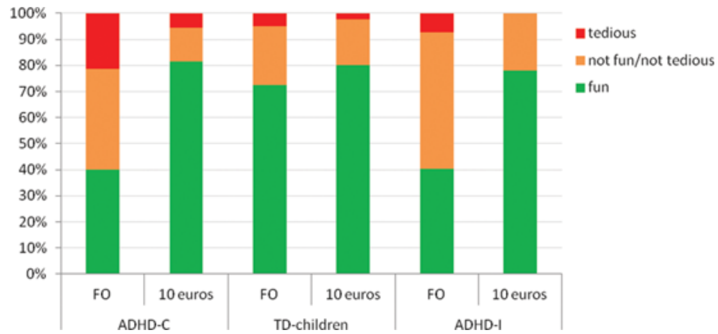

FIGURE B Proportion of answers of children with ADHD-I (n = 27), ADHD-C (n = 70) and typically-developing (TD; n = 40) children on the questions: "What did you think of the task with the curl and the cross?"(FO) and "what did you think of the task with the 10 euros?" (10 euros). Possible answers were: fun, not fun/not tedious, tedious.

APPENDIX C

A. The reinforcement instruction for the first presented task version in the Feedback-Only condition (translated from Dutch; from Dovis et al., 2013):
On this task, do your best and try to perform as accurately as possible.
If you reproduce a sequence of squares correctly, a green curl will appear on the screen.
If you reproduce a sequence of squares incorrectly, a red cross will appear on the screen.
You can also monitor how you are doing by looking at the bar at the bottom of the screen.
If you reproduce a sequence correctly the bar gets longer, and if you reproduce a sequence incorrectly the bar gets shorter.

B. The reinforcement instruction for the second presented task version in the Feedback-Only condition (translated from Dutch; from Dovis et al., 2013):
On this task, do your best and try to perform as accurately as possible.
If you reproduce a sequence of squares correctly, a green curl will appear on the screen.
If you reproduce a sequence of squares incorrectly, a red cross will appear on the screen.
You can also monitor how you are doing by looking at the bar at the bottom of the screen.
If you reproduce a sequence correctly the bar gets longer, and if you reproduce a sequence incorrectly the bar gets shorter.
When the task is finished, a purple screen will appear.

C. The reinforcement instruction for the first presented task version in the 10 euros condition (translated from Dutch; from Dovis et al., 2013):
With this task, you can earn these 10 euros (*instructor shows euros and places them in sight above the laptop keyboard*).
If you have earned these 10 euros, you can take them home and do with them what you want: These 10 euros are then yours.
You can earn these 10 euros by performing well enough on this task
If you reproduce a sequence of squares correctly, a green curl will appear on the screen with a picture of the 10 euros next to it. This indicates that you have an increased chance to get these 10 euros.
If you reproduce a sequence of squares incorrectly, a red cross will appear on the screen with a picture of the 10 euros behind it. This indicates that you have a decreased chance to get these 10 euros.
Only when you have made enough correct reproductions a green screen will appear: You are then finished with the task, and you can take the 10 euros home and keep them.
But beware. If you make too many incorrect reproductions, a red screen will immediately appear: Then you will also be finished with the task, but you will not get the 10 euros (then I'll take back the 10 euros).
I don't know how many correct reproductions are required to get a green screen or how many incorrect reproductions are required to get a red screen; the computer decides this randomly.
You can also monitor how you are doing by looking at the bar at the bottom of the screen.
If you reproduce a sequence correctly the bar gets longer, and if you reproduce a sequence incorrectly the bar gets shorter.

D. The reinforcement instruction for the second presented task version in the 10 euros condition (translated from Dutch; from Dovis et al., 2013):

Only by performing well enough on this last part of the task you can earn these 10 euros.

<u>You will now go on to the last part of the task and the following still applies:</u>

If you have earned these 10 euros, you can take them home and do with them what you want:

These 10 euros are then yours.

You can earn these 10 euros by performing well enough on this task

If you reproduce a sequence of squares correctly, a green curl will appear on the screen with a picture of the 10 euros next to it. This indicates that you have an increased chance to get these 10 euros.

If you reproduce a sequence of squares incorrectly, a red cross will appear on the screen with a picture of the 10 euros behind it. This indicates that you have a decreased chance to get these 10 euros.

Only when you have made enough correct reproductions a green screen will appear: You are then finished with the task, and you can take the 10 euros home and keep them.

But beware. If you make too many incorrect reproductions, a red screen will immediately appear: Then you will also be finished with the task, but you will not get the 10 euros (then I'll take back the 10 euros).

I don't know how many correct reproductions are required to get a green screen or how many incorrect reproductions are required to get a red screen; the computer decides this randomly.

You can also monitor how you are doing by looking at the bar at the bottom of the screen.

If you reproduce a sequence correctly the bar gets longer, and if you reproduce a sequence incorrectly the bar gets shorter.