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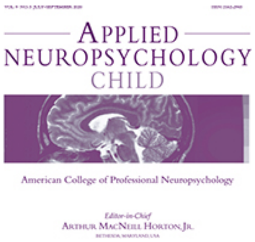

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Exploring neuropsychological effects of a self-monitoring intervention for ADHD-symptoms in school

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ABSTRACT

Children who have symptoms of Attention Deficit/Hyperactivity Disorder (ADHD) often experience disruptive and off-task behavior and lower school performance than would be expected based on their cognitive abilities. These behavior and achievement difficulties are a challenge to teachers, who often provide inclusive education for children with ADHD. This study explored whether a self-monitoring intervention can help children with ADHD-symptoms to reduce off-task behavior as well as improve their cognition. The participating children were seven boys in special needs education with an age between nine and twelve. The students used an interval timer to remind themselves to monitor whether they were still on task. During math classes, observations, teacher ratings and neuropsychological tests were assessed. The results showed that off-task behavior was significantly reduced during the period the interval timer was used compared to baseline (reduction from 46.8 to 27.3%), as measured by observations (effect size: $\eta^2_p = .83$) and this was confirmed by teacher ratings (effect size: $\eta^2_p = .69$). With respect to cognition, children only showed significant improvements in inhibition (effect sizes: *Cohen's* $d = 2.62$ and 1.24). The teachers as well as students evaluated the intervention mainly as positive. In line with previous studies, we found that that a self-monitoring intervention can be beneficial for children with ADHD-symptoms. Larger studies including a control group and blind observers are necessary to establish these results and to investigate the underlying mechanisms.

KEYWORDS
ADHD; classroom behavior; nexecutive functions; intervention; self-monitoring

Introduction

> *"Only when I am taking a test, I get distracted and I get off into my own little world. I get to draw, paint, and whatever I want"* (ADHD Voices, 2012).

Children with symptoms of Attention Deficit/Hyperactivity Disorder (ADHD) often experience difficulties in school that can manifest in off-task behavior, as in the given example, but also in disruptive behavior (American Psychiatric Association, 2013). These behaviors can severely impact upon academic achievement (Daley & Birchwood, 2010; Barry, Lyman & Klinger, 2002). Children with ADHD often have poor grades, poor standardized reading and mathematics test scores, and an increased likelihood of repeating a school year (Loe & Feldman, 2007). As ADHD is a common childhood disorder with increasing prevalence rates over the past few years (Batstra, Nieweg, Pijl, Van Tol, & Hadders-Algra, 2014; Bachmann et al., 2017; Stephenson, Karanges, & McGregor, 2013; McCarthy et al., 2012; Zuvekas & Vitello, 2012; Health Council of the Netherlands, 2014), there is a necessity for effective classroom interventions. Especially because in many countries inclusive education is obligated by the government, meaning that all children, also the ones with disabilities, need to attend and be welcomed by neighborhood schools in age-appropriate, regular classes and be helped and supported to participate in all aspects of the life of the school (Kerpel, 2014; Ledoux, 2016; McManis, 2017; Mittler, 2000). Children with symptoms of ADHD also need to be able to attend a regular school and should receive help to achieve success. In

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this study we, therefore, investigate a self-monitoring intervention that aims to improve classroom behavior in children with symptoms of ADHD, and we explore the neuropsychological mechanisms by testing for improvements in executive functions.

The reason to explore the neuropsychological mechanisms is that executive functions play an important role in the relationship between ADHD and academic performance (Biederman et al., 2004; Daley & Birchwood, 2010). Children with ADHD and poor executive functions scored lower on academic performance than children with ADHD and sufficient/good executive functions (Biederman et al., 2004). In children without ADHD, impaired executive functioning turned out to have less influence on academic performance. There seems to be an interaction between ADHD, executive functioning, and academic functioning. One of the most prominent neuropsychological theories of ADHD, the executive function theory of ADHD, states that ADHD symptoms are caused by an impairment in executive functions (Willcutt, Doyle, Nig, Faraone, & Pennington, 2005). Willcutt et al. (2005) showed that ADHD was associated with significant weakness in different domains of executive functions (i.e. response inhibition, vigilance, flexibility, planning, verbal working memory, and spatial working memory). Especially response inhibition and working memory problems are common in children with ADHD (Barkley, 1997; Tannock, 1998; Rennie, Beebe-Frankenberger, & Swanson, 2014). Problems with response inhibition are more typical of younger children with ADHD-symptoms, whereas problems with working memory are more typical of older children with ADHD-symptoms (Brocki & Bohlin, 2006). It should be kept in mind, however, that these statements are based on group means, meaning that no individual conclusions can be drawn; poor skills in executive functioning are neither necessary nor sufficient for an ADHD-diagnosis. Interestingly, working memory is a main predictor of academic achievement in individuals with ADHD (Fried et al., 2016). Working memory deficits did also have an impact on children without ADHD; however, this impact was not significant. Individuals with ADHD as well as working memory deficits seem to suffer from “the detrimental synergism of the two conditions such that their academic performance is severely compromised when both are present” (Fried et al., 2016, p. 492). Considering previous findings, it can be concluded that poor executive functions play an important role in academic problems of children with ADHD (Biederman et al., 2004; Sjöwall & Thorell, 2014).

Children with ADHD-symptoms often struggle with self-regulatory ability, meaning that children can experience difficulties maintaining on-task behavior and managing or controlling their behavior (Harris, Friedlander, Saddler, Frizzelle, & Graham, 2005). Self-regulation is connected with self-regulated learning, which is defined as the self-directing process and attitudes that stimulate a student to convert mental skills to performing skills in school (Zimmerman, 2008). Self-regulated learning is a pro-active process that students use to acquire academic skills, such as setting goals, selecting and using strategies, and self-monitoring their own effectivity. According to Zimmerman (2008), self-regulation consists of three phases: the forethought phase, the performance phase and the self-reflection phase. In primary education the forethought and self-reflection phase are primarily regulated by the teacher. The self-monitoring intervention in the present study targets the performance phase of the model of Zimmerman (2008) by training self-control and self-observation during math lessons. Many cognitive studies indicated that self-monitoring problems may contribute to behavioral problems of children with ADHD (see, for a review, Shiels & Hawk, 2010). Due to these self-monitoring difficulties, children with ADHD are less able to self-observe when they are off-task (as exemplified in the opening citation) or disruptive during class and less able to self-correct their behavior. Our self-monitoring intervention aims to train students to apply self-monitoring in order to decrease these problems.

During the intervention an interval timer will remind the students to monitor whether they are still working on task. In the beginning, the interval timer prompts self-monitoring. We expect that the monitoring skill taught by the interval timer will be trained. In this way, the monitoring skill is internalized and the student is more capable of self-regulated learning. This training might lead to either an improvement in executive functions or the child’s ability to deploy self-regulation in the classroom. Self-monitoring interventions are easily accessible and can be used for children with and without an ADHD diagnosis, as long as they experience difficulties with self-regulatory strategies and self-monitoring (Hoff & Ervin, 2013). Most classroom interventions for ADHD focus on classroom management strategies that teachers apply including consequence-based and antecedent-based strategies (DuPaul, Eckert, & Vilardo, 2012; Gaastra, Groen, Tucha, & Tucha, 2016). The advantage of self-monitoring interventions is that children themselves are taught new self-regulatory skills.

Previous studies indeed demonstrated positive effects of self-monitoring interventions in the classroom for children with ADHD-symptoms. Bruhn, McDaniel, and Kreigh (2015) analyzed 41 studies in their meta-analysis and reported consistent evidence that classroom behavior of children with ADHD could be substantially improved by a self-monitoring intervention. A recent comprehensive meta-analysis compared effectiveness of different types of classroom interventions for ADHD, and concluded that both self-regulation interventions (including self-monitoring interventions) and consequent-based management strategies (i.e., making use of reward and response cost schedules) are most effective for managing ADHD (Gaastra, Groen, Tucha, & Tucha, 2016). The majority of effect studies (over 80%) use single-subject designs with fewer than 10 participants, which is due to practical restrictions of this type of research; such as time-consuming daily observations and low numbers of children with ADHD in the classroom. Grossi (2002) furthermore showed that self-management is a useful behavioral tool for inclusive education settings.

The present study is performed in a naturalistic setting on a school for special education, and aims to replicate previously demonstrated behavioral effects and additionally to explore effects on executive functions. Three research questions are answered: (a) Is a self-monitoring intervention in the classroom effective in reducing off-task behavior in students with ADHD-symptoms; (b) Is a self-monitoring intervention effective in improving executive functions (inhibition, attention regulation, and simple auditory working memory); and (c) What are the experiences of the teachers and students with the self-monitoring intervention in the classroom?

Methods

Setting

This study took place in a special needs primary school in the North of the Netherlands. The school has more than 200 students divided into 15 classrooms and includes children with different behavioral or learning problems. The school has a care team with for example psychologists, remedial education experts, and social workers.

Participants

Children with ADHD-symptoms are the target population in this study. The sample contained seven boys with ADHD-symptoms from two classrooms of special needs primary education selected by remedial education experts and teachers of their school. Inclusion criteria were a minimum age of 8, a minimum IQ of 85, and the presence of ADHD-symptoms. These ADHD-symptoms were objectified by an ADHD screening questionnaire. The students selected were supposed to have problems with their work ethic during independent seatwork, to be capable of reflecting on themselves during the intervention according to their teacher and remedial education expert. Table 1 shows the age and IQ scores of the participants. The neuropsychological profile based on the pretest of the neuropsychological tests is also shown in Table 1. The instrument section contains information about these tests.

Furthermore, we asked parents and the two teachers to complete a questionnaire about the students, to check whether the students actually show symptoms of ADHD. A description of this questionnaire can be found under ‘Instruments’. The results show that all participating students show inattentive and/or hyperactive/impulsive behavior according to their teacher and/or parents. Table 2 shows the results of the disruptive behavior disorder rating scale (DBD) and whether the students have a diagnosis of ADHD and/or medication. Five students had an official DSM 4 or DSM 5 diagnosis, diagnosed by a mental health care institution. Two students had no formal diagnosis, but obtained scores on the questionnaire that were consistent with the students diagnosed with ADHD.

Instruments

Questionnaire

Different instruments were used for this study, starting with a questionnaire: the Dutch version of the DBD (Oosterlaan et al., 2008; Original version: Pelham, Gnagy, Greenslade, & Milich, 1992). This instrument was used to guarantee that the selected students were in line with the target population. The DBD measures symptoms of the behavioral disorders ADHD, ODD, and CD in children between 6 and 16 years old.

Cognitive tests

To investigate the effects of the intervention on cognition, neuropsychological tests were used at the beginning (pretest) and the end (post-test) of the study. The tests used were the “Digit Span” of the Wechsler Intelligence Scale for Children-Third Edition-Netherlands (WISC-III-NL) (Kort et al., 2002; Original version: Wechsler, 1991) for measuring simple working memory, “Auditory Attention and Response Set” and “Inhibition” of the NEPSY-Second Edition-Netherlands

Table 1. Age, IQ, and neuropsychological test scores.

S	Age (year; months)	TIQ	VIQ	PIQ	PS	Digit span[a]	Auditory attention total correct[b]	Response set total correct[b]	Inhibition total errors[b]	Inhibition - naming self-corrected errors[b]	Inhibition - inhibition self-corrected errors[b]	Inhibition - shifting self-corrected errors[b]
1	10:00	89.0	88.0	92.0	91.0	6[d]	≥76	51–75	26–50	11–25	2–5[d]	11–25
2	9:05	[c]	94.0	71.0	65.0	5[d]	≥76	11–25	51–75	≥51	≥76	26–50
3	11:06	95.0	99.0	91.0	83.0	9	≥76	<2[d]	51–75	≥51	51–75	≥76
4	11:10	[c]	91.0	71.0	75.0	6[d]	≥76	6–10[d]	11–25	2–5[d]	26–50	6–10[d]
5	9:09	98.0	105.0	92.0	–	6[d]	≥76	26–50	26–50	11–25	≥76	2–5[d]
6	12:00	98.0	102.0	94.0	94.0	7	≥76	11–25	51–75	6–10[d]	51–75	26–50
7	9:09	95.0	97.0	94.0	91.0	9	≥76	<2[d]	26–50	11–25	26–50	26–50
M (*SD*)	10.10 (1.20)	95.0 (3.7)	96.6 (6.0)	86.4 (10.6)	83.2 (11.3)							

Note. S = Student; TIQ = Total IQ; VIQ = Verbal IQ; PIQ: Performance IQ; PS = Processing speed.
[a]Standardized *W* score ($M = 10$, $SD = 3$).
[b]Standardized P-score ($M = 50$, $SD = 34$).
[c]Missing score because of verbal-performance discrepancy;
[d]Low or very low score.

(NEPSY-II-NL) (Zijlstra, Kingma, Swaab, & Brouwer, 2010; Original version: Korkman, Kirk, & Kemp, 2007) to measure attention regulation and inhibition, respectively. The WISC is a test for determining the intellectual capabilities of children from 6 up to and including 16; the NEPSY is for identifying the neuropsychological development of children from 5 up to and including 12. To limit the influence of attention span in measuring simple working memory, the score for Digit Span was separated in Digit Span Forward and Digit Span Backward, whereas Digit Span Backward is less contaminated by differences in attention span than the Digit Span overall score. For the post-test, parallel versions of the Digit Span and Inhibition were used.

Observations

The effect of the intervention on classroom behavior was analyzed by observations. In both classrooms, two researchers observed for six weeks 19 arithmetic lessons in classroom A and 20 in classroom B by using an observation scheme. Because on-task behavior seemed difficult to operationalize (Gill & Remedios, 2013), we scored off-task behavior in the observations. This off-task behavior was based on Ardoin and Martens (2004) and is a simple derivative of the scale developed by Barkley, Fischer, Newby, and Breen (1988). During the observations, cycles of one minute were used in which every student was observed for ten seconds. After every ten seconds of observing, there were five seconds to score the behavior of the child. Scoring possibilities were "looking around," "playing with objects," "peer interaction," and "out of seat" (Table 3).

When a student showed one or more of these behaviors in the interval of ten seconds, the observers independently scored the corresponding category. Observations were only scored during periods of independent seatwork, and not during instruction time. The number of behaviors in each category were counted for these periods and divided by the total number of minutes of independent seatwork. If a student's behavior corresponded with two categories, both were scored. For the total score, they however counted as one off-task behavior.

Teacher ratings

Together with the observations, teacher ratings were used for analyzing the behavioral effects of the intervention. After every arithmetic lesson, the teacher scored the on-task behavior of the child during that lesson on a 5-point Likert scale. Possible answers were: 1 = poor, 2 = weak, 3 = moderate, 4 = reasonable, 5 = good.

Table 2. Diagnoses ADHD, medication, and scores on DBD according to teachers and parents.

Stud.	Diagnosis	Medication	DBD teacher AD	DBD teacher H/I	DBD parents AD	DBD parents H/I
1	Yes	Methylphenidate	Clinical	Subclinical	Clinical	Clinical
2	No	None	Clinical	Average	Average	Average
3	Yes	None	Subclinical	Average	Clinical	Subclinical
4	No	None	Clinical	Clinical	Subclinical	Subclinical
5	Yes	Methylphenidate	Clinical	Clinical	Average	Average
6	Yes	Methylphenidate	Subclinical	Clinical	Average	Average
7	Yes	Dexamphetamine	Clinical	Clinical	Clinical	Clinical

Note. DBD = disruptive behavior disorder rating scale; AD = attention deficit; H/I = hyperactive/impulsive.

Table 3. Explanation scoring possibilities observation form off-task behavior.

Category	Explanation
Looking around	The student is gazing around the classroom
Playing with objects	The student is manipulating an object or body part (like hair) that has nothing to do with the learning activity
Peer interaction	The student is initiating contact or responding (verbally or physically) to another student without permission
Out of seat	The student's weight is not being supported by the chair

Interval timers

The device used for the intervention was the Interval Training Timer produced by Everlast® (Everlast, n.d.). Every student received this timer which vibrated every five minutes. This vibration reminded the students to monitor themselves for working on their task. To make them more aware of their own behavior and their on-task behavior, after every vibration the students had to fill in on a form whether they were still working on their goal behavior (Appendix B). The students had to choose a happy smiley when they were working on their goal behavior, a neutral smiley when they were working partly on their goal behavior, and a sad smiley when they were not working on their goal behavior.

Procedure

The ethical committee of the department of Psychology of the University of Groningen provided ethical approval for the study. The teachers and remedial education experts selected the students. A meeting was scheduled to inform the school and the teachers about the intervention and their role in this project. The parents of the selected children were contacted by phone to inform them about the intervention and the study. All parents were willing to collaborate and gave informed consent after reading an information letter. Subsequently, the parents and teachers filled in the DBD.

The observational data were analyzed based on an A-B-A design. The neuropsychological test data were analyzed based on a pre-post design. The study lasted six weeks, the intervention period three weeks. The procedure for every week is shown in Figure 1. To check whether the students could work with the interval timer and the observation sheets, a practice session was organized with all students; all students were able to work with the intervention. The intervention took place during the daily arithmetic lessons to warrant a comparable and relatively stable situation. After six weeks, the teachers and students were interviewed individually about their experiences with the intervention.

Analysis

The research questions about the effect of the intervention on behavior and on executive functions were answered by quantitative research. The observations of off-task behavior during the arithmetic lessons were first described by a line diagram including all categories of off-task behavior. Possible differences for every category between the time periods were described and consequently tested by a generalized linear model (GLM) repeated measures test. For the GLM repeated measures test all time points within a time period were aggregated. The percentage of off-task behavior (for all different categories) was the dependent variable; time (baseline, intervention period and post intervention) was the independent variable. The teacher ratings were also described by a line diagram. All time points within a time period were aggregated and with a GLM repeated measures test it was tested if there were any significant differences between the time periods. The teacher rating of on-task behavior was the dependent variable and time was the independent variable.

The scores of the neuropsychological tests were described by the use of a table with all scores and the results of the t-test. In the *t*-test, the scores of the pre-test were compared with the scores of the post-test on the neuropsychological tests. The scores were the dependent variables and time was the independent

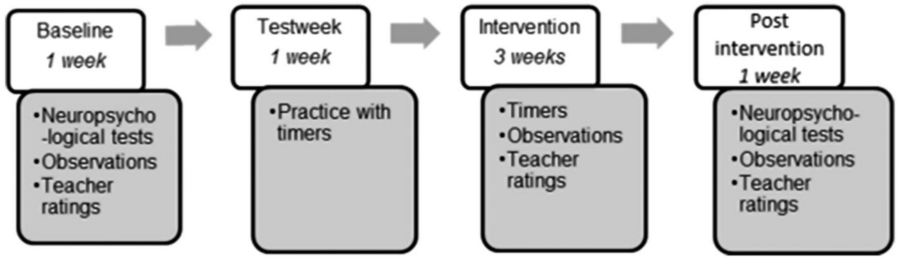

Figure 1. Procedure for every week during the study.

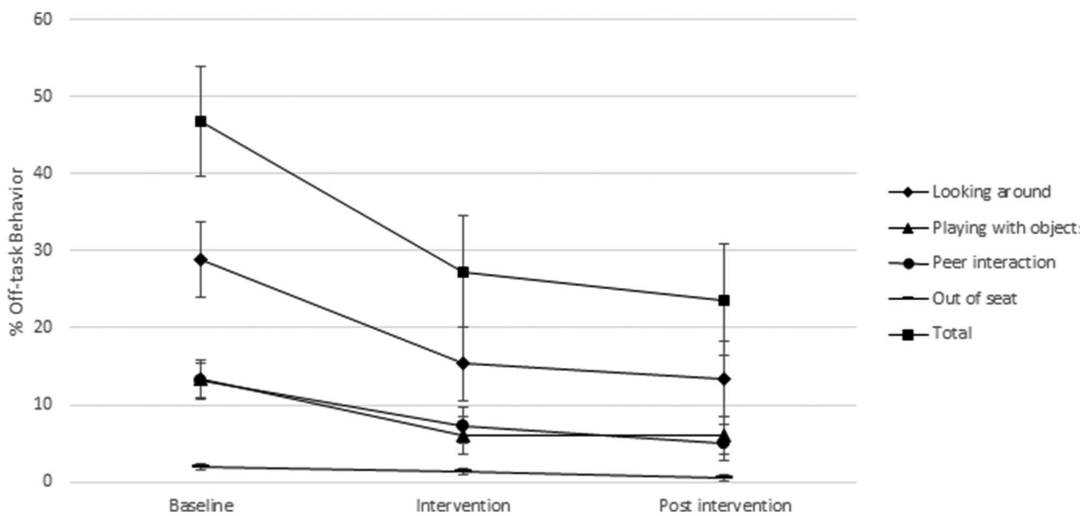

Figure 2. Percentage off-task behavior per time period by observations (raw data points are in Figure A1 of Appendix A).

variable. For the GLM repeated measures test and the t-test, a significance level of $\alpha = .05$ was used.

The research question about the evaluation of the intervention was answered by qualitative research. The interviews with teachers and students were analyzed in search for conspicuities and points mentioned frequently.

Results

Effect on behavior

Observations

Figure 2 shows a decline for all categories of off-task behavior in the intervention period. Only for the category "out of seat" do the scores seem to be relatively stable and low; this seems to be a floor effect. After cessation of the intervention, the scores for total off-task behavior, "looking around" and "peer interaction" are still declining with a less steep slope. The category "out of seat" again seems to be relatively stable and the scores for the category "playing with objects" are increasing after the end of the intervention. Figure A1 of Appendix A shows the total off-task behavior for every student per time point.

Table 4 shows that the three time periods differed significantly with large effect size for all categories of observations, except for "peer interaction." The contrasts between the different periods show that particularly the intervention period differed from the baseline period. For the total off-task behavior, the contrast between baseline period and intervention period is significant ($F = 29.802$, $df = 1$, $p = .002$, $\eta^2_p = .832$) and the contrast between intervention period and post intervention period is not ($F = 1.827$, $df = 1$, $p = .225$, $\eta^2_p = .233$). This pattern was similar for the subcategories "looking around" and "playing with objects." For the subcategory "peer interaction" no significant change was apparent from baseline to the intervention period (most likely due to large variability during baseline), but "peer interaction" behaviors reduced during the post intervention period ($F = 29.802$, $df = 1$, $p = .002$, $\eta 2p = .810$). For the subcategory "out of seat" no significant differences were observed.

Teacher ratings

Figure 3 shows the teacher ratings of on-task behavior per time period.

Table 4 . Means, standard deviations, and GLM-repeated measures test results of observations of off-task behavior (in %) and teacher ratings of on-task behavior (score 1–5)[1].

	Baseline (*SD*)	Intervention (*SD*)	Post intervention (*SD*)	*F*	*df*	Sig.	η^2_p
Total	46.8 (11.2)	27.3 (7.4)	23.6 (10.9)	20.8	2	<0.001*	0.776
Look around	28.8 (10.5)	15.3 (6.2)	13.3 (6.8)	22.9	2	<0.001*	0.793
Objects	13.4 (7.0)	6.0 (3.9)	6.1 (4.9)	7.6	2	0.007*	0.560
Peer interaction[a]	13.1 (10.3)	7.3 (4.6)	5.1 (4.1)	3.1	1.011	0.129	0.340
Seat	2.0 (1.1)	1.3 (0.8)	0.5 (0.6)	6.8	2	0.011*	0.529
Teacher ratings	3.2 (0.8)	4.0 (0.5)	4.1 (0.3)	13.8	2	0.001*	0.697

Note. [a]Greenhouse-Geiser used due to violation of assumption of sphericity.
*$\alpha = 0.05$.
[1]One of the teachers mentioned that one of the children did not receive his medication on one of the days in the postintervention period, and therefore his behavior differed from normal. The scores of this child for this day are not included in the GLM-repeated measures. This correction led to a small difference in *F* value, but no difference in *p* value.

Table 4 shows that the teacher ratings in Figure 3 differ significantly per time period and that the effect size is large. While the contrast between baseline and intervention period is significant with large effect size ($F = 13.498$, $df = 1$, $p = .010$, $\eta^2_p = .692$), the difference between intervention period and post intervention period does not reach significance ($F = .251$, $df = 1$, $p = .634$, $\eta^2_p = .040$).

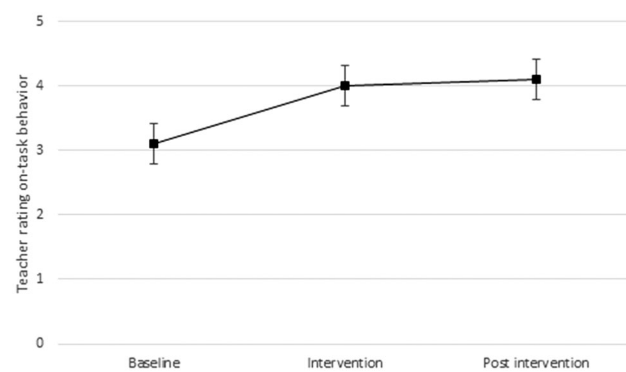

Figure 3. Teacher ratings of on-task behavior for all students per time period.

Effect on cognition

Neuropsychological tests were used to measure the effect of the intervention on cognition by comparing the pre- and post-test.

The results of the paired *t*-test presented in Table 5 show that there are some positive changes for "Digit span" and "Auditory attention and response set" with small to large effect sizes, although these differences are not significant. However, there are significant positive changes with large effect sizes in "Inhibition," for total incorrect and self-corrected incorrect in naming.

Evaluation of intervention

According to the teachers involved in this study, the intervention is useful and applicable in practice. However, the intervention period should be longer and/or contain more lessons. Both teachers reported the use of the timer as beneficial and as a relatively independent process self-directed by the child. This resulted in more time for positive feedback. One of the teachers did not see an effect of the intervention. The other teacher did, especially in the beginning, when the children felt highly responsible. The teacher who did not see an effect mentioned that he would have introduced other children retrospectively, assuming the intervention is more helpful for children with problems with on task behaviors, not necessarily those with ADHD-symptoms. He mentioned that selecting the target group of the intervention deserves better consultation with the teacher and the remedial education expert. The other teacher mentioned the possible strength that it is necessary to keep on communicating with children so that they continue to feel responsible.

The majority of the students were positive about the intervention as a whole. Two students were more neutral. The timer and the process of the intervention were easy for almost all children. One of them described the timer as irritating and found the sound of the vibration too loud. Only one student said the intervention did not help him, two students said the intervention helped them a little and three students said the intervention helped them much. All students except one (the one for whom the intervention did not help) did like to use the device again. Suggestions of the students are "using the timer at their own discretion" and "the timer having more gentle and shorter vibration." The form the students had to fill out was sometimes experienced as distracting and some children experienced it as taking too much space on their table.

Discussion

Principal findings

This study investigated whether a self-monitoring intervention could help children with symptoms of

Table 5. Pre–post comparisons of neuropsychological test scores.

	Pre (*SD*)	Post (*SD*)	*t*	*df*	Sig.	Cohens d^a
Digit span	10.0 (1.4)	10.9 (2.3)	−.891	6	.407	−.470
Digit span forward	6.00 (0.8)	6.00 (1.3)	0	6	1	0
Digit span backwards	4.00 (1.0)	4.86 (1.2)	−1.867	6	.111	−.774
AA total correct	29.3 (1.3)	29.6 (0.8)	−1.549	6	.172	−.082
RS total correct	28.0 (4.9)	30.1 (4.7)	−1.343	6	.228	−.437
I total incorrect	14.6 (6.8)	8.9 (5.8)	7.071	6	<.001*	2.623
I-naming self-corrected incorrect	1.6 (1.1)	0.4 (0.8)	2.489	6	.047*	1.238
I-inhibition self-corrected incorrect	2.1 (2.8)	1.9 (1.3)	.258	6	.805	.090
I-shifting self-corrected incorrect	5.0 (3.2)	5.0 (3.5)	0	6	1	0

Note. AA: auditory attention; RS: response set; I: Inhibition. [a]Calculated based on Equation 9 of Lakens (2013).
*$\alpha = 0.05$.

ADHD in the classroom in reducing off-task behavior and improving executive functions. The classroom observations showed a decline in off-task behavior in the intervention period compared to baseline and these effects lasted in the week after cessation of the intervention (postintervention). The time periods differed significantly from each other for all categories of off-task behavior, except for "peer interaction." Also, the teacher ratings of on-task behavior differed significantly between the time periods, with a positive effect between baseline period and intervention period and a remaining effect post intervention. The nonsignificant improvement in "peer interaction" may be explained by the fact that peer behaviors are more dependent on external stimuli than the other observed behaviors. The significant improvements in on-task behavior/reduced off-task behavior show a positive effect of the intervention in line with findings of recent meta-analyses by Bruhn, McDaniel, and Kreigh (2015) and Gaastra, Groen, Tucha, and Tucha (2016) and confirm that classroom behavior can be improved by means of a self-monitoring intervention. Classroom interventions appear to be one of the most effective interventions for improving classroom behavior (Gaastra, Groen, Tucha, & Tucha, 2016).

The effects of the intervention on executive functioning were less consistent than the effect on behavior. The results showed no significant differences for simple working memory and attention regulation. Inhibition showed improvements in some aspects with large effect sizes, which is in line with findings of Ramos-Galarza and Pérez-Salas (2018) who recently suggested that monitoring compensates for poor performance of inhibitory control in children with ADHD. However, a re-testing effect may partly explain the improved performance; learning effects resulting from the repeated assessment can unfortunately not be excluded, because the present study did not include a nonintervention control group that also underwent repeated assessment. Causal attribution should therefore be made with caution.

Strengths and limitations

This study has several strengths and limitations. Regarding the reliability and validity of this study, a strength is the use of two observers. The inter-observer reliability was high. The researchers introduced the intervention to the children and were present during the intervention period, which guaranteed that the intervention was properly implemented, leading to high treatment integrity. A disadvantage may have been that the observers were not blinded, which possibly could have biased the results even though the standardized observation form limited this influence. The teacher ratings, on the other hand, were more subjective. The teachers were aware of the intervention, which may possibly have biased their ratings. Due to this, teacher ratings during the intervention may have been more positive than the actual change in behavior. Another strength is that the observations during the baseline condition contained at least three time points, even though it was not stable for all participants (large variability of behaviors during baseline is common in children with ADHD). However, for four students there was less than 25% overlap between the baseline condition and intervention period, which indicates a stable effect.

The social validity of this intervention is high. The intervention is performed in the natural environment of the students; their own classroom. As skills learned in a laboratory setting often show poor transfer to tasks in daily life, effects in the natural environment are an important strength of this study. Testing this intervention in school therefore increases the validity of results, since the intervention aims to improve skills in an educational setting, which might transfer to other settings in daily life. Taking into account the experiences of the pupils and teachers with the intervention in the classroom is also valuable, as this demonstrates the social validity. The intervention is easy to establish in practice, because it does not imply much additional work for teachers and the process is relatively autonomous for children. The intervention is time and cost effective. Furthermore, significant improvements of classroom behavior may also benefit the classroom climate. A limitation of the intervention is however that some students found the timers and the recording sheets distracting from the task. A solution for this issue could be the use of a digital self-monitoring application. Bruhn, Waller, and Hasselbring (2016) investigated digital developments in self-monitoring, which led to using technology to both prompt and record self-monitored behaviors. Furthermore, the intervention turned out not being appropriate for each student. The target group of the intervention should be defined more precisely in the future, with more attention for problems with on-task behaviors and impulse control instead of a focus on inattentive behavior. This is in line with findings of Ramos-Galarza and Pérez-Salas (2018), arguing that monitoring compensates poor performance in inhibitory control in adults with ADHD. Future studies on the neuropsychological mechanisms of this intervention may provide clues for determining the exact target group. Future research should also take into account medication use and how this affects the intervention effects. We investigated a naturalistic setting and included a mix of medicated and un-medicated students.

An important limitation of this study is that the sample consisted of only seven children. In future research, larger studies are necessary to make more definite statements about the neuropsychological effects. In addition, the intervention period consisted of only three weeks, which is comparable to other studies assessing self-monitoring interventions (Bruhn, McDaniel & Kreigh, 2015). However, this is a relatively short period to expect effects of the intervention regarding neuropsychological functioning (Diamond, 2012). Furthermore, more sensitive instruments for measuring the executive functions could have been utilized in order to make more valid statements about the neuropsychological effects. Even though already after three weeks behavioral effects were observed, a longer intervention period may have stronger and more lasting results and may give a more reliable picture of the behavior of the students. There may for example be a delay of effect (Reichow, 2011), which can be observed in the individual observational data of some students (Appendix A, Figure A1). Furthermore, this study did not contain a control group without intervention, causing that we could not control for potential third variables such as effects of social support during the intervention.

Another discussion point is the use of the intervention in two classrooms, meaning that two teachers were involved. It is reassuring that positive intervention effects appeared in both classrooms based on individual results. However, for the statistical analyses we could not separate classrooms, because of low sample sizes. The intervention was only performed during arithmetic lessons, and therefore it is unclear whether the effects will generalize to other lessons.

Some students were capable of correctly reflecting on their own behavior and competences. However, based on observations and score forms of the students, it turned out that not all students were able to correctly evaluate their own behavior. Some students may suffer from a positive illusory bias, which is common in children with ADHD (Owens, Goldfine, Evangelista, Hoza, & Kaiser, 2007). This means that children evaluate their own competences surprisingly high in contrast to their actual competences. A positive illusory bias may lead to an underwhelming effect for some students, because these students have more difficulties with understanding that there is a situation that could be improved. In future studies, self-evaluation could be targeted for improvement by providing feedback to the students about their self-observation, that is, by comparing student ratings to teacher ratings (Ardoin & Martens, 2004).

Future research

Future research should include studies with a randomized controlled design to draw more firm conclusions. It is recommended to use blinded observers, in order to prevent the observers from having knowledge of which child is using the intervention, as this could possibly influence the observation. There is growing evidence that self-monitoring interventions are useful to improve off-task and disruptive behaviors in classroom; however, research on the underlying (neuropsychological) mechanisms of these cognitive processes is lacking until now. Repeated neuropsychological assessments would provide insights into these mechanisms as well as the most optimal duration of the intervention to achieve improvements in neuropsychological functions. Furthermore, future research might evaluate neuropsychological effects by using more sensitive tests and more tests per domain of executive functions to gain more reliable and validated results about the constructs measured. Additionally, direct (psychophysiological) measures of performance monitoring could be added (e.g., Shiels & Hawk, 2010).

Adding feedback to the intervention could be meaningful. Harris et al. (2005) argue that children with ADHD perform better when they are regularly provided with feedback by the teacher during self-monitoring. Since some students may suffer from positive illusory bias (Owens, Goldfine, Evangelista, Hoza, & Kaiser, 2007), feedback might provide them with more insight into their own behavior. Adding feedback also allows the teacher to determine the length of time that students require external support in order to begin being able to deploy a self-monitoring strategy on their own in the classroom. This insight might contribute to more appropriate expectations of the abilities of the child and the actual effects of the intervention.

Conclusion

Some students seem to clearly benefit from a self-monitoring intervention, with an average to large effect on observed classroom behavior. The effect on cognition seems pertained to inhibition. However, causal attribution should be made with caution. Further research with a large number of participants and a control group is necessary to control for a potential testing effect and confounding factors. The evaluations with teachers and students supported the promising conclusions and social validity of the intervention.

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Appendix A

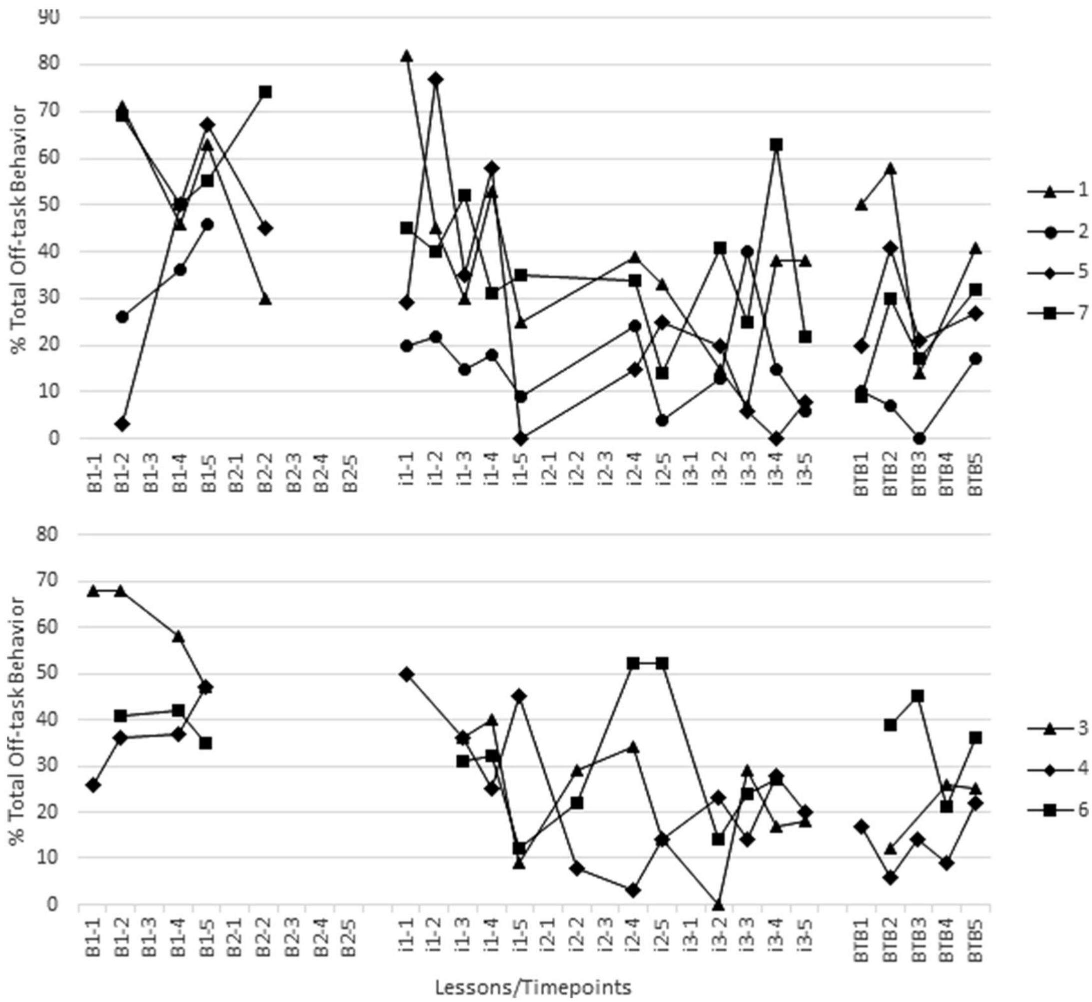

Figure A1. Percentage off-task behavior per time point per student by observations, divided by classroom (B: Baseline, i: intervention, Pi: Post intervention).

Appendix B

Self-score form

Name: Date:

My goal behavior is……………………………………………………………………..………….

Am I still on-task?

Yes A bit No

1.
2.
3.
4.
5
6
7.
8.