Behavioral Inhibition Improvement Through an Emotional Working Memory (EWM) Training Intervention in Children with Attention Deficit/Hyperactivity Disorder

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ABSTRACT

The study was undertaken to examine the effects of a short-term Emotional Working Memory (EWM) training program on executive reaction of time and executive functions. The sample of 20 children with Attention Deficit/Hyperactivity Disorder (ADHD) was randomly assigned to a EWM training (n = 11) and an active control group (n = 9). Our study hypothesized that an increase in ADHD inattention and ADHD impulsive during the first weeks of the referral would lead to weak executive functions in the control group, but not in the EWM training group, due to the EWM intervention. The results revealed the beneficial effects of executive functions in the EWM group, but not in the control group. According to our data, executive reaction ability of time increased in the EWM training group but remained unchanged in the control group. Even a rather short intervention of 1.5h can protect children with ADHD from weak executive functions at the beginning of the referral.

Key Words: Emotional Working Memory (EWM), training program; behavioral inhibition, ADHD inattention, ADHD impulsive

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Introduction

Studies have shown that neurodevelopmental disorder is an important factor of deficient inhibition (Chamberlain *et al*., 2008). Individual differences in Behavioral Inhibition System (BIS) are related to various forms of psychopathology (Li *et al*., 2015), such as depression (e.g., Pinto-Meza *et al*., 2006), anxiety (e.g., Fowles, 1988), and addiction behaviors (e.g., Wardell *et al*., 2013). In a structural equation model, Li *et al*. (2015) found significantly higher BIS activity levels for depressed female adolescents compared with the depressed male adolescents. Leen-Feldner *et al*. (2004) examined 'how individual differences in behavioral inhibition relate to rumination, a response style associated with prolonged periods of negative affect, particularly depression' among young adults. He reported that individual variation in behavioral inhibition is associated with negative emotional reactivity, and behavioral inhibition is related to dysfunctional styles of regulating emotional distress. Other evidence is the study of Wardell *et al*. (2013) who studied the role of behavioral inhibition system in the associations between mood and alcohol consequences in college. He showed that behavioral inhibition system moderated within-person associations between negative mood and alcohol consequences.

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Barkley (1997a) has shown that behavioral inhibition phenomenon in BIS is related to at least three major components. Component 1: Behavioral inhibitors such as prepotent response, stopping current response or interference control; Component 2: Executive functions as the behavioral reaction to potential inhibitors, with indicators such as working memory, self-control, inner speech and rebuilding; Component 3: Behavioral inhibition outcomes such as motor control and fluency syntax.

Researchers have been shown that inhibitory control is associated with executive functions (Barkley, 1997a,b) as well as behavioral inhibition outcomes among children (Li *et al*, 2008). Other studies widely recommended relationship between executive functions and behavioral inhibition outcomes as a serious issue for many children (Bannon *et al*., 2002). Of the available studies, Barkley (1982a,b; 1997; 1998) showed that high executive functions levels are associated with motor control among children with ADHD. Other studies pointed at high improvement rates of executive functions, motor control and fluency syntax among children with ADHD (Kalff *et al*., 2003; Raggio, 1999; Maccoby, 1980; Denkla and Rudel, 1978; Ge *et al*., 2017; Le *et al*., 2016; Wang *et al*., 2016).

Fuster (1989 and 1995) give evidence for impacts of behavioral inhibition and the executive functions on control, timing, sustainability, flexibility, novelty complexity and construction of targeted motor actions. Prefrontal cortex controls motor output, and planning and the execution of motor responses and behavioral inhibition were controlled by adjacent areas of the cerebral cortex. Therefore, large and fine motor skills are related to behavioral inhibition (Barkley, 1997a,b).

Children with ADHD have to face different problems, such as learning reading and math, getting into contact with other students, focusing in the classroom, participating in extracurricular activities, and managing their tests, that can be seen as potential deficient inhibition factors (e.g. Rubia *et al*., 2005; Li *et al*., 2016). Some studies demonstrated that writing, drawing and speaking among children with ADHD are lower compared with their peers (Barkley, 1982a,b; 1997; 1998). Emotional Working Memory (EWM) strategies might be helpful to foster such challenges. EWM strategies might function as a kind of coping strategy to help children to be effective to control inhibitorsIn a study Schmeichel *et al*. (2008) showed the relationship between working memory and emotions described EWM as a serious issue for many children.

Given that many studies recommended EWM strategies for children (e.g. Rapport *et al*., 2013; Schweizer and Dalgleish, 2011), it would be expected that EWM training programs might be associated with children's executive functions. The present study addressed two interrelated theoretical predictions from EWM strategies theory and research. The first was whether EWM training programs, as an experimental intervention, would relate to ADHD children's executive functions. The second focus of the present investigation was to test the effectiveness of a rather short-term intervention of about 1.5 h that easily can be implemented at psychiatry clinic with little investment of time.

EWM refers to performance of short term memory to encode, maintain and manipulate emotional information (Schweizer *et al*. (2011). EWM is important as ability to identify, understand and regulate emotions (Schweizer *et al*. 2013). We expect that EWM training programs have positive effects on executive functions (e.g. Rapport *et al*, 2013; Baddeley, 2001; Schweizer and Dalgleish, 2011; Morrison and Chein, 2011; Joormann, Levens and Gotlib, 2011). The use of EWM strategies, taught in EWM training programs, may help a person significantly to progress in memory processes, which is related to emotional disorders (Joormann, Levens and Gotlib, 2011).

Many scholars have examined relationships between EWM and executive functions in general (Miller, 2014). In a review study Best and Miller (2014) demonstrated that inhibitory control ability among participants with low working memory capacity is lower during Go/Nogo study compared with high working memory capacity. Wright and Diamond (2014) reported significant correlations between EWM strategies and inhibition with a sample of 96 children 6–10 years. In a recent cross-sectional study Traverso *et al*. (2015) investigated the relationship between inhibition and working memory in preschoolers. They showed a positive effect of both verbal and spatial working memory on response inhibition tasks for preschoolers. EWM has been shown to be a predictor of executive functions in process models of EWM in the occupational context, with executive reaction of time as a mediator between EWM and executive functions. High EWM capacity is expected to lead to increase in executive reaction ability of time; executive reaction ability of time should lead to improve executive functions and performance.

The present study is meant to gain more knowledge about the effects of a EWM training program on executive functions for children with ADHD. The indicators commitment error and omission error were used for executive functions (Verbruggen and Logan, 2008; Wodka *et al*., 2007). In addition, the indicator executive reaction of time was included as an important time-related outcome variable (Verbruggen and Logan, 2008). As children with ADHD have to get used to different conditions at the beginning of the referral, we used the variables ADHD inattention and ADHD impulsive (Swanson *et al*., 2006).

Based on the literature review that provided reasons why ADHD inattention and ADHD impulsive lead to an increase of commitment error and omission error in the first weeks of the referral, we hypothesised EWM training program prevent such an increase. We expected growing commitment error and omission error in the control group, but the experimental group should not, due to the intervention. In this paper we focus on the following two research questions: 1) Is EWM training program in commitment error and omission error beneficial for children with ADHD at the beginning of the referral or not, and 2) what is the impact of EWM on executive reaction of time.

Method

Design

To investigate the effect of EWM training program on behavioral inhibition improvement in children with ADHD, an experimental design was carried out based on a pretest–posttest control group design with a EWM training program. In this study, an alternative training program of the same length and comparable structure and training methods was offered to participants of the active control group, but with a different content.

EWM training program

The training used in the intervention is EWM training which Wright and Diamond (2014), for example, has confirmed the relationship between EWM training and executive functions based on psychological theory and research. In current studies, EWM training programs have often been based on self-help literature (e.g. Alloway, Gathercole, & Pickering, 2006; Carlson, 2005). In the present study, a EWM training program similar to dual n-back task theory described by Schweizer *et al*. (2013) was slightly modified and used. We integrated the following trials in our training program: a face (for 500ms) on a 4×4 grid on a monitor and a word (for 500–950ms) over headphones. Training participants learned to response each picture-word pair by a 2500ms interval via button press. Schweizer and Dalgleish (2011) stated that 'if either/both stimuli from the pair matched the corresponding stimuli presented *n* positions back'. Another explanation is that 60% of the words (e.g., death or rape) and faces (anger, fear or sorrow) were emotionally negative with the others affectively neutral in tone. The task had an audio and visual feedback. With respect to the last trials, participants were instructed to formulate concrete implementation intentions for their tasks. All EWM techniques taught in our training concentrated on short range planning, focusing in particular on the following day.

Sample and procedure

20 children with ADHD, including female student at level of elementary (about 75%) and secondary (about 25%) at a Chinese psychiatry clinic, randomly were assigned to a EWM training group (n = 11) and an active control group (n = 9). We selected the appropriate age group with a mean of 10.25 years (SD = 2.96) and excluded unsuitable exercise subjects. There were no differences concerning age (EWM group: M= 10.25, SD = 3.46; control group: M= 10.31, SD = 2.92) and prior grade point average (EWM group: M= 1.54, SD = .55; control group: M= 1.29; SD = .46). Additionally, we made effort to select participants of similar sexes, ages, and task.

For the EWM training, we implemented a 1.5h EWM training program in children with ADHD > 8 years of age. For the control group, something about how to develop training courses for the occupational context was learned. Important aspects of the phases were discussed in the control group: 1) before an intervention, such as the definition of training goals, to consider the motivation of trainees to attend training or knowledge of the trainees, 2) during an intervention, such as the use of different media and methods or the structuring of training programs, 3) after an intervention, such as ways to support transfer and persistence after the course such as reminder mails or meetings. We balanced the amount of trainer input and length of practice period in the EWM group and control group and offered small cards to remind each participant of the most important points. We conceptualized the training programs as short interventions, lasting for 1.5h. Consequently, we explored a rather short EWM intervention in contrast to previous intervention studies (e.g. Alloway, Gathercole, & Pickering, 2006).

All 20 participants filled in questionnaires measuring the five variables, ADHD inattention, ADHD impulsive, executive reaction of time, commitment error and omission error, directly before and 3 weeks after the intervention. Any of these participants from the EWM group and the control group were not withdrawn from the study. It has to be mentioned that children could attend the EWM training program as part of their tasks. It is an obligation for every child to take part in different tasks in the first referrals. This explains the missing of drop-outs. We chose 3 weeks as the time interval between the first and second time of measurement because we wanted to explore the effects of the training program on commitment error, omission error and executive reaction of time in the first weeks of referral. We assigned children to small groups. They received their course on different days at the beginning of the referral. The sub groups of EWM group varied in size from 2 to 10 participants, which most the sub groups consisted of 6 to 9 children. One out of four trainers trained each group. At the beginning of the training, we informed all participants about the procedure and the treatment of their data. Participation was voluntary. We assured the confidentiality of responses. Participants were emphasized to the importance of correct and honest responses.

Measures

ADHD inattention and ADHD impulsive

We used the scales ADHD inattention and ADHD impulsive of the fourth version of Swanson, Nolan & Pelham IV scale (SNAP-IV) questionnaire (Swanson *et al*. 2006). The scales cover ratings of ADHD behavior one has to face. The scale consisted of three items. The reliability and validity of the scale were supported by empirical evidence. We obtained an alpha coefficient of 0.81.

Commitment error and omission error

We used the scales commitment error and omission error of the version of Hoffman (1984) questionnaire as indicator of executive functions (Wodka *et al*., 2007). While the scales ADHD inattention and ADHD impulsive reflected the perception of ADHD behavior one has to deal with, the scales commitment error and omission error measured the internal cognitive-emotional perception of external behavioral inhibitors in particular. The scales cover negative aspects of executive functions. The scales consisted of two items. Empirical evidence supported the reliability and validity of the scale (Verbruggen and Logan, 2008). We obtained an acceptable alpha coefficient ($\alpha = 0.86$).

Executive reaction of time

Executive reaction of time was measured with a version of the scale executive reaction of time of the EWM Scale (Schweizer *et al*., 2011 and 2013), which consists of two items in the original version (face and word. The content of the scale covers a dual n-back computer task. We obtained an alpha coefficient of 0.79.

Results

To prove the three research hypotheses, the control group and EWM group were compared in a two-way MANOVA model with group membership as a between-subject factor, and the time of measurement (pre-training and post-training) as a within subject factor. The correlations between the five dependent variables (ADHD inattention, ADHD impulsive, commitment error, omission error and executive reaction of time) at time 1 is shown in Table 1, while the average scores and standard deviations of the control group and EWM group are given in Table 2. In addition, Table 3 gives the results for the overall effects of the two-way MANOVA model as well as for the five different dependent variables. According to the following descriptive of all the test scores for the whole sample and specified for the experimental and control group, a significant time effect with $F(5,14)=5.67^{*}$ and a significant time × training interaction with $F(5,14) = 3.79^{**}$ was observed. We didn't observe significant group effect in the overall analysis. An increase of ADHD inattention, $F(1,18)=5.54^{**}$, and ADHD impulsive, $F(1,18)=4.69^{**}$, commitment error, $F(1,18)=2.88^{*}$, omission error, $F(1,18)=3.72^{*}$, was resulted by the significant time effect. According to the results in Table 2, we can see a significant increase of ADHD inattention ($M=2.60$, $SD=0.53$ at time 1, and $M=2.69$, $SD=0.56$ at time 2), $t(8)=2.45$, $\rho= 0.006$ (one tailed), $\varepsilon'=0.34$, and ADHD impulsive ($M=2.65$, $SD=0.54$ at time 1, and $M=2.72$, $SD=0.57$ at time 2), $t(8)=2.36$, $\rho= 0.004$ (one tailed),

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ε'=0.46 in the control group, but no significant for commitment error (M=2.26, SD=0.46 at time 1, and M=2.22, SD=0.49 at time 2), t(10)=1.53, ρ= 0.067 (one tailed), ε'=0.25, and omission error (M=2.19, SD=0.49 at time 1, and M=2.16, SD=0.53 at time 2), t(10)=1.48, ρ= 0.053 (one tailed), ε'=0.22 in the EWM group. In the overall MANOVA, a significant interaction, F(5,14)=3.79*, resulted due to a significant interaction concerning commitment error, F(1,18)=4.23*, and omission error, F(1,18)=5.24*, as well as reaction of time, F(1,18)=4.97*. Commitment error, (M=2.16, SD=0.48 at time 1, and M=2.31, SD=0.49 at time 2), t(8)=2.76, ρ<0.001 (one-tailed), ε'=0.41, and omission error, (M=2.11, SD=0.51 at time 1, and M=2.24, SD=0.57 at time 2), t(8)=2.11, ρ<0.001 (one-tailed), ε'=0.39 increased in the control group, and remained stable in the EWM group. While executive reaction of time improved in the EWM group, (M=3.34, SD=0.65 at time 1, and M=3.39, SD=0.68 at time 2), t(10)=2.66, ρ=0.034 (one-tailed), ε'=0.51, no changes occurred in the control group, (M=3.36, SD=0.59 at time 1, and M=3.31, SD=0.55 at time 2), t(8)=2.91, ρ=0.028 (two-tailed), ε'=0.34.

Our study obtained no interaction effects for ADHD inattention and ADHD impulsive. With respect to the amount of ADHD inattention, ADHD impulsive and executive functions levels, there are only a few children who experienced high levels of ADHD inattention and ADHD impulsive hardly ever (6.5%) and who experienced deficient inhibition hardly ever (9.01%).

Discussion

With respect to the first hypothesis, children with ADHD reported an increase of ADHD inattention and ADHD impulsive in the first weeks of the referral in the control group. A tendency of increased ADHD inattention and

Table 1. Correlations between the three dependent variables at time 1 (n = 20)

	Variables	M	SD	1	2
1	ADHD inattention	2.26	0.51		
2	ADHD impulsive	2.21	0.49		
3	Commitment error	2.16	0.56	0.54**	
4	Omission error	2.27	0.61	0.53**	
5	Reaction of time	3.28	0.55	-0.47**	-0.38**

**p<0.01

Table 2. Average scores and standard deviations of the control group and EWM group

Variable	EWM group (n=11)				Control group (n=9)			
	Pre-training		Post-training		Pre-training		Post-training	
	M	SD	M	SD	M	SD	M	SD
ADHD inattention	2.59	0.51	2.63	0.55	2.60	0.53	2.69	0.56
ADHD impulsive	2.64	0.53	2.68	0.57	2.65	0.54	2.72	0.57
Commitment error	2.26	0.46	2.25	0.49	2.16	0.48	2.31	0.49
Omission error	2.19	0.49	2.17	0.53	2.11	0.51	2.24	0.57
Reaction of time	3.34	0.65	3.39	0.68	3.36	0.59	3.31	0.55

Table 3. Multiple analysis of variance for training and time

		Variable		
		Training	Time	Time × Training
ADHD inattention df=1,18	F	0.89	5.54**	0.31
	Partial η^2	0.02	0.06	0.01
ADHD impulsive df=1,18	F	0.76	4.69**	0.43
	Partial η^2	0.04	0.03	0.02
Commitment error df=1,18	F	0.05	2.88*	4.23*
	Partial η^2	0.01	0.04	0.00
Omission error df=1,18	F	0.09	3.72*	5.24*
	Partial η^2	0.02	0.03	0.01
Reaction of time df=1,18	F	0.37	0.46	4.97*
	Partial η^2	0.01	0.00	0.00
Overall df=5,14	F	0.87	5.67**	3.79*
	Partial η^2	0.06	0.04	0.01

*p < 0.05, **p < 0.01

ADHD impulsive was found in the EWM group, but no significant effect. As the second hypothesis, participants in the control group reported an increase of commitment error and omission error, but we did not find a significant effect in the EWM group. As the third hypothesis, the results give evidence for the expected improvement in executive reaction of time in the EWM group, but we did not find changes in the control group.

Basis of the same concept under our study, according to study data, the first weeks of the beginning referral at psychiatry clinic are marked by a strong increase in ADHD inattention and ADHD impulsive for children with ADHD in the control group. It is quite reasonable that ineffective attention control, as well as time-related ADHD inattention and ADHD impulsive such as behavior regulated ability, and other new and unfamiliar challenges are potential deficient inhibition factors for most of the children with ADHD. We hypothesized, that potential inhibitors should go along with a decrease of ADHD inattention and ADHD impulsive in our participants. Our hypothesis was supported for participants by the reported results in the control group, which were demonstrated prototypically the expected increase of ADHD inattention and ADHD impulsive.

In the EWM group we found a tendency in the same direction, but no significant effect. The EWM training program seems to lessen the increase in executive ADHD inattention and ADHD impulsive. While for all children with ADHD similar inattention and impulsive occurred in the first weeks, the EWM training program might have been useful for executing ADHD inattention and ADHD impulsive as less threatening and for developing better strategies for dealing with ADHD challenges.

The reported increase in ADHD inattention and ADHD impulsive was reflected by an increase in commitment error and omission error with medium effect size in the control group, while no changes were found in the EWM group: A clear evidence for the effectiveness of the EWM intervention on executive functions. It was expected that the development without the EWM training program would be marked by a significant increase in commitment error and omission error, as can be seen in the control group. The participants of the EWM training program showed no such increase. Go and Nogo, which are major drivers of commitment error and omission error, were affected by the EWM intervention. Consequently, the data suggest that a EWM training program can be a specific tool to prevent ADHD inattention and ADHD impulsive from becoming reflected in higher levels of commitment error and omission error. The results support former findings showing positive effects of EWM training programs on executive functions (Wright and Diamond, 2014; Traverso *et al.*, 2015) and indicators of executive functions (Best and Miller, 2014) in the occupational context. Our experimental intervention study supports a conclusion: Executive reaction of time improved in the EWM group. We did not examine executive reaction of time and executive functions at different points of measurement after the intervention with a time lag. Therefore, we cannot prove the assumption that the attendance at the EWM training program led to improve executive functions of time, which led to a decrease in executive functions.

There are other possible explanations concerning potential mediators linking EWM training programs to executive functions. One explanation is that through the use of the described EWM strategies, potentially inhibitory events can be anticipated and emotionally improved resulting in positive effects on executive functions.

Our study made methodological improvements, including the use of randomization, an active control group and a rather homogeneous intervention, in the examination of the effectiveness of a EWM training program on executive functions. The study had a number of limitations, which could induce further research. To obtain more effectiveness of a EWM training program, future research could hide the aim of the study. Another limiting aspect is that our study assumed that our trainers were not able to influence the results in such a differentiated way that an interaction effect for commitment error and omission error and executive reaction of time but not for ADHD inattention and ADHD impulsive resulted.

We focused on commitment error and omission error and executive reaction of time as dependent variables in this study. Besides these variables the impact of EWM training interventions on cognitive performance should be examined. In process models of EWM, it is assumed that the use of EWM strategies leads to more executive reaction ability of time, which positively influences performance. In our study, nearly all children with ADHD of the first referral of psychology attended EWM training program.

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Our study recommends the integration of EWM interventions in curricula at school, especially for children with ADHD, who suffer from EWM problems. With a small investment of 1.5 h, an increase in commitment error and omission error could be diminished. With respect to our results, EWM training programs appear to be a helpful tool.

Although popular literature on EWM is increasing year by year, there are a lot of research questions concerning the use of time and its effects on executive functions that remain open. With respect to the use of EWM training programs, we should know more about the effectiveness of other training courses. The results demonstrate that even a rather short intervention can have positive effects on executive functions and can be used as a kind of prevention strategy to deal with growing ADHD inattention and ADHD impulsive.

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