Cognitive training for children with ADHD: Individual differences in training and transfer gains

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Chapter 6

Summary and general discussion
Summary and general discussion

The last decade, the amount of non-pharmacological treatments for children with ADHD has increased tremendously, especially interventions aimed at improving executive functions (EFs) have found its way into clinical practice. It was thought that targeting these underlying neurological substrates and core cognitive deficits assumed to mediate ADHD causal pathways could potentially lead to greater transfer and generalization to functioning in everyday life. This shift towards the development of interventions that directly target EFs is even more understandable when one considers the impact of these neurocognitive deficits on functioning in everyday life such as academic performance (e.g. Gathercole, Pickering, Knight & Stegmann, 2004) and the inability of worldwide recommended multimodal approaches (e.g. combination of pharmacological and psychological treatments) to improve those ecologically valid outcome measures in children with ADHD (Jensen et al., 2007; Van der Oord, Prins, Oosterlaan & Emmelkamp, 2008a). At the start of this thesis in 2011 there were several EF targeted intervention studies that showed promising findings on both near (i.e. improvement in untrained tasks similar to the domain of the trained task) and far transfer measures (i.e. improvements in domains other than the trained process). However, at that time only few studies also incorporated academic outcome measures which is remarkable given that this key area of functioning in everyday life is often disturbed in children with ADHD (Loe & Feldman, 2007). Simultaneously there was a growing demand for evidence-based implementable interventions in a school setting for children with EF related behavior and learning difficulties (such as children with ADHD) in regular educational settings in the Netherlands. Evidence-based and standardized interventions that could both support the teacher and the child with EF problems were scarce at that time.

The current thesis was aimed at determining whether cognitive training would be effective for school-aged children with ADHD (aim 1) and whether transfer, both in terms of classroom behavior as well as academic performance, could be improved with an innovative classroom embedded approach (aim 2). Moreover, it was aimed at obtaining a more finer-grained knowledge of factors that might influence the efficacy of training such as underlying mechanisms, individual differences and training features (aim 3). This chapter
summarizes the main findings of the different chapters throughout this thesis and ends with a general discussion and implications for future research and practice.

**Summary**

Chapter 2 describes the results of the randomized controlled trial which was aimed at replicating and extending previous Cogmed Working Memory Training (CWMT) studies in children with ADHD by investigating the short and long-term effects on neurocognitive, behavior and academic outcome measures. Children in the active control group received a new cognitive training called ‘Paying Attention in Class’ (PAC) which contained a working memory and a compensatory executive function training. One hundred and five children with ADHD between the age of 8 and 12 years were randomly assigned to either CWMT or the PAC intervention. For both interventions, children received treatment from trained developmental psychologists during school hours outside the classroom. Results showed that children in both groups improved on measures of attention, working memory and inhibition directly after treatment. These results were supported by improvements found on parent rated executive functioning and parent and teacher rated ADHD related behavior. On the long term, children in both groups improved on measures of working memory, inhibition, planning, parent and teacher rated ADHD related behavior and teacher rated executive functioning. One superior effect of CWMT was found; children who followed CWMT performed better on a visual spatial working memory task. Children did not improve on measures of academic performance, behavior in class and quality of life. Conclusively, both on the short and long-term children improved on broad neurocognitive measures and parent and teachers executive functioning and ADHD related behavior ratings.

The aim of the study presented in chapter 3 was to explore whether clinical and initial cognitive abilities predicted or moderated the neurocognitive and academic performance outcome measures of aforementioned RCT. Investigated predictor and moderator variables were use of medication,
comorbidity, subtype of ADHD, initial verbal working memory skills and initial visual spatial working memory skills. Results showed that use of medication and initial verbal - and visual spatial working memory skills predicted and moderated near transfer measures. Irrespective of type of training, children with initial ‘below average’ or ‘average’ working memory (either verbal or visual spatial) skills benefitted most over time in terms of performance on an attention - and visual spatial working memory task. CWMT was more beneficial in terms of a visual spatial working memory task for children who used medication during training and children with initial ‘below average’ or ‘average’ verbal working memory skills. Subtype of ADHD and comorbidity predicted and moderated far transfer measures. In terms of parent and teacher rated behavioral regulations problems, children with the ADHD-Inattentive subtype temporarily benefitted most from cognitive training in general. Additionally, children with the ADHD-Inattentive subtype in the CWMT group also benefitted most on the long term regarding teacher rated behavioral regulation - and metacognition problems. Finally, in terms of word reading accuracy, children with the ADHD-Combined subtype and children without comorbid disorders (i.e. learning disabilities or other behavioral disorders) benefitted most on the short term from cognitive training in general.

In order to extend our understanding of the individual differences in both near and far transfer measures of the new PAC intervention, an additional group of 116 children with ADHD received this intervention. In chapter 4 it was investigated which demographical, clinical and baseline neurocognitive characteristics predicted individual treatment response six months after treatment, based on a clinical significant improvement in working memory. Results showed that initial sustained attention skills, initial verbal working memory skills and teacher rated metacognition problems at baseline predicted individual treatment response. Children with lower sustained attention and verbal working memory skills and less teacher rated metacognition problems were more likely to be non-responders to treatment. Subsequent analyses revealed that non-responders only improved on near transfer measures (verbal and visual spatial working memory) and parent rated questionnaires. In contrast, both the partial responders and responders improved on most far
transfer outcome measures with most profound effects for the responders. Responders benefitted significantly more in terms of visual spatial working memory, teacher rated metacognition problems, direct learning conditions (i.e. concentration, motivation, work rate, task orientation) and the parent rated quality of life scales psychological well-being and school environment. These results imply that a clinical (significant) improvement in working memory was an important prerequisite to obtain improvements in far transfer measures as well. A small group of non-responders that additionally followed CWMT only improved on a measure of visual spatial working memory.

In chapter 5 we focused on individual differences in performance gains during the working memory training of the PAC intervention and investigated how individual differences in learning curves influenced transfer measures directly after training and which variables could predict those learning curves. Based on the sample described in chapter 4, data of the trained verbal and visuospatial working memory task was analysed with a latent growth curve model (LGCM). Results showed that for both trained tasks, there were individual differences at the beginning of training and individual differences in children’s linear growth trajectories. The individual differences at the start of training were predicted by age and intelligence, however the individual differences in learning curves were not predicted by any of the baseline variables. Children with larger gains on the trained verbal working memory task showed larger gains on a near transfer verbal working memory measure. The linear growth trajectories of the trained visuospatial working memory task did not affect the visuospatial outcome measure. Finally, the academic performance outcome measures were not affected by the linear growth trajectories of the trained verbal or visuospatial task.
Summary and general discussion

General discussion

Near and far transfer effects of cognitive training
The first aim of this thesis was to establish whether cognitive training (i.e. CWMT and PAC), implemented at school, would be effective for school-aged children with ADHD. The most important findings from our RCT were that, irrespective of the type of training, children improved both on the short and long term on several neurocognitive outcome measures. Previous treatment effects of CWMT on verbal working memory (Holmes et al., 2010; Hovik et al., 2013) and attention (Egeland et al., 2013; Klingberg et al., 2002; Klingberg et al., 2005) were not found, only a treatment effect on a visual spatial working memory task could be replicated. In terms of behavioral outcome measures, parents and teachers also reported improvements in executive functioning and ADHD related behavior for both groups indicating transfer to functioning in everyday life. Especially the improvements in teacher rated questionnaires are promising as evidence from previous studies in this area has been scarce. However again, treatment effects of CWMT on parent ratings of ADHD related behavior (Beck et al., 2010; Klingberg et al., 2005) and executive functioning (Beck et al., 2010) could not be replicated. The overall null findings in academic performance measures contrasted with some previous effect studies of CWMT (Egeland et al., 2013; Green et al., 2012) however these results are more in line with recent meta-analyses (Rapport et al., 2013; Cortese et al., 2015; Orban et al., 2015).

So what can we conclude from these results? Is cognitive training effective for children with ADHD and should it be added to the list of effective non-pharmacological interventions? Why couldn’t we replicate the treatment effects of CWMT that were found in previous studies? And why are our results only partly in line with these recent meta-analyses? How can two interventions that are different in their nature and treatment features lead to almost similar treatment outcomes? To answer these important questions, we need a broader picture of factors that possibly contribute to the effects of cognitive training. Therefore, we have to dig deeper and focus on factors such as underlying mechanisms, individual differences and training features.
Figure 1, which is based on the review article of Von Bastian and Oberauer (2013), depicts an oversight of how these factors are integrated with the findings of current thesis and thereby providing a basis for this general discussion.

**Methodological confounding factors**

Although previous studies (e.g. Green, Strobach & Schubert, 2014; Morrison & Chein, 2011; Shipstead et al., 2010; 2012) have extensively elaborated on the methodological issues around cognitive training, several of these issues (right side of Figure 1) are readdressed below as they are particularly important for the interpretation of the results presented in current thesis. In contrast to previous effect studies of CWMT, our RCT contained an active control group (PAC) whose experience was closely matched to the training group in terms of effort, active training time and performance related feedback.

This overcomes the possibility that the trained and control group approach the post assessment differently in terms of motivation (Shipstead, Hicks et al., 2012) and also ensures that the expectations of parents and teachers is equal for both conditions. It should be mentioned though that our RCT did not contain a third randomized ‘no treatment’ control group. Therefore confounders such as test-retest effects, passage of time, expectancy and effort effects cannot be ruled out. Parent and teachers were aware that children received an active treatment and teachers were actively involved in the PAC intervention, which could have inflated the parent and teachers ratings. Meta-analyses have shown that effects of ADHD ratings after cognitive interventions drop to non-significant if outcomes of probably blinded raters are considered (Cortese et al., 2015; Sonuga-Barke et al., 2013). Choosing and developing control groups remains challenging for future trials as ethical constraints make it difficult to implement ‘no treatment’ groups and there still is no consensus about how a control group should be designed (Von Bastian & Oberauer, 2013). Nonetheless, it is advisable that, next to an active control group, future studies include a third ‘no contact’ randomized control group with well blinded measures of behavioral outcomes.
Figure 1. Factors possibly influencing cognitive training outcomes

**Summary and general discussion**

**Figure 1. Factors possibly influencing cognitive training outcomes**

- **Intervention specific features**
  - intensity & duration
  - paradigm
  - algorithm

- **Individual differences**
  - age
  - intelligence
  - initial cognitive ability
  - comorbidity
  - subtype
  - medication
  - personality
  - motivation
  - biological factors
  - beliefs in malleability

- **Specific working mechanisms**
  - Enhanced capacity/enhanced efficiency
  - Assessment during treatment:
    - neuro imaging studies
    - strategy questionnaires

- **Non-specific working mechanisms**
  - treatment adherence
  - skills therapist
  - support teacher and parent

- **Progress trained task(s)**
  - Verbal working memory

- **Effects cognitive training**
  - interception only

- **Methodological confounders**
  - Test-rest test effect, passage of time, expectancy effect

- **Treatment outcome**
  - 

Factors that (possibly) contributed to findings of current thesis

Factors that should be investigated in future research
An additional methodological factor that should be considered in light of current findings concerns the way in how far transfer measures were assessed. For cognitive measures, a general recommendation that arises from the literature refers to the use of multiple tasks per cognitive domain (e.g. Morrison & Chein, 2011; Shipstead et al., 2010). Using only one single task merely reflects transfer of task-specific rather than task-general improvements. Despite the fact that we made a well-balanced decision in terms of including cognitive measures, some cognitive domains (visual spatial working memory, planning and inhibition) were represented by one single task and should therefore be interpreted with caution. For example, the replicated treatment effect of CWMT on visual spatial working memory that was found in chapter 2 was based on one single task that shared similar features with many of the trained tasks within CWMT.

Findings in terms of academic outcome measures also seem to be greatly dependent on the way how they are assessed. An important strength of our study was that, in contrast to many previous studies, we included long term assessments of academic performance measures. These long-term assessments are necessary as a child will need to exploit his or her improved working memory capacity and this will only be visible after a lengthy period of time (Gathercole, 2014). Nonetheless, no improvements were found on any of the academic performance measures. Many studies, including ours, contained standardized ability tests that tap into cumulative achievements which makes them strongly dependent on prior learning and relatively insensitive to recent changes in learning capacities (Gathercole, 2014). Actual school measures such as national academic tests or grades could possibly offer a better assessment of academic performance during a certain period of time. Another factor that could explain why we didn’t find any improvement in academic performance measures is the fact that the correlations between the academic outcome and working memory measures in current study were quite low (chapter 5). The academic outcome measures that were used in current study were quite basic tasks which required less working memory capacity than more complex tasks such as reading comprehension or mathematic problem solving (Dehn, 2008).
Summary and general discussion

Therefore, academic outcomes measures that predominantly depend on working memory capacity should be included in future studies.

Conclusively, these methodological considerations bring us a bit closer to understanding the inconsistent findings in transfer effects throughout the cognitive training literature and provide some starting points for future research designs. However, to address the remaining questions regarding the putative underlying mechanisms and individual differences, a further examination of factors that potentially contributed to the observed near and far transfer effects is necessary.

Specific working mechanisms
The middle part of Figure 1, which refers to the potential underlying working mechanisms, will be discussed hereafter. The putative mechanism behind process-based interventions such as CWMT is based on the assumption that extensive training of a specific cognitive skill strengthens the common and overlapping neural EF network which in turn leads to improvements in untrained tasks or activities that rely on the same neural network (Klingberg, 2010). This would imply that the more the executive function improves during training, the larger the transfer effects will be. So far, there is no direct evidence for this mechanism in ADHD samples (Van der Oord & Daley, 2015) although some studies provide indirect evidence opposing this hypothesis as they found far transfer effects in the absence of near transfer effects (Chacko, Bedard et al., 2014; Dovis et al., 2015; Egeland et al., 2013; Van Dongen-Boomsma et al., 2014). Results of chapter 4, although indirectly, provide some support for this aforementioned hypothesis as it was found that children with the largest gains in working memory skills (responders) after following the PAC intervention showed a broader and stronger pattern of far transfer improvements. In chapter 5 we further elaborated this hypothesis by investigating how improvements in working memory capacity during the PAC training influenced near and far transfer measures. Results showed that children with larger verbal working memory training gains (i.e., steeper training curves) had larger benefits on the untrained verbal working memory composite score, indicating near transfer. However, these training
gains did not affect the academic outcome measures and no effects of visuospatial training gains on transfer measures were found. Additionally, both in the verbal and the visuospatial WM training, the model explained 15-20% of the variance in the initial WM levels and 2-8% in training gains. These results provide limited support for this putative neural mechanism of working memory training and also illustrates that training gains are affected by many different factors, hence the large proportion of unexplained variance. As this hypothesis stems from the neural correlates of executive functioning, evidence from neuro-imaging studies in ADHD samples is indispensable and should be incorporated in future trial designs.

Another plausible specific mechanism that could account for transfer is the increase of working memory efficiency (Von Bastian & Oberauer, 2013). For example, the acquisition of knowledge and skills (e.g. strategy use) during training could lead to more efficient use of the available working memory capacity. This account has been supported by a recent study of Dunning and Holmes (2014) which showed that training related improvements in working memory were accompanied by implicit and spontaneous changes in use of strategies in healthy adults. Although there are some indications that spontaneous increased use of strategies during process-based working memory training occurs in children with ADHD as well (Holmes et al., 2010), this hasn’t been systematically investigated so far. As for the PAC intervention, children practiced with several strategies throughout the training so there is a possibility that this led to a more efficient use of the available working memory capacity. However, one would need questionnaires that could map the strategy use during training to provide evidence for this mechanism. As long as direct evidence of these specific mechanisms of increased working memory capacity and efficiency is lacking, it might be more rewarding considering the potential contribution of non-specific treatment factors to near and far transfer findings.

**Non-specific working mechanisms**

Non-specific factors such as therapeutic alliance, the therapist’s competence and adherence to treatment protocol refer to dimensions that are shared
by most therapies and have shown to contribute to treatment outcome in psychotherapy (Chatoor & Krupnick, 2001). Especially therapeutic alliance, i.e. the quality of the relationship between the patient and therapist, has been shown to be a reliable predictor of positive treatment outcome in psychotherapy (Ardito & Rabelinno, 2011). So far this has received little attention in cognitive training literature. However, it is likely that this factor made a contribution to the findings in current thesis. CWMT and PAC differ in their nature and treatment features, nonetheless they led to quite similar outcomes. The common factor of both intervention groups was that they received equal amounts of interaction time with a therapist in which children learned to cope with frustrations (due to increasingly demanding tasks) and were encouraged to proceed even if they failed. This may imply that it does not matter what you do (either process-based versus more strategy based training) instead it has been suggested that how an activity is done is more important and that the personal characteristics of those leading a program can have major effects on how beneficial a program is (Diamond & Ling, 2015). Although the treatment protocols were standardized and the therapists received similar training beforehand it is plausible that, given the large amount of therapists that were necessary to conduct the studies in current thesis, treatment alliance varied which in turn could have influenced the efficacy of training. Therefore, we suggest that future trials should monitor these non-specific therapist factors and incorporate these findings in treatment outcome analyses. The Client Direct Outcome Information (CDOI) method of Duncan, Miller and Sparks (2004) is a good example of a model that can used in future research.

Another non-specific treatment factor that could have contributed to the observed effects is the use of incentives during training. Next to models that view executive dysfunction as a causal model for ADHD, there are also models emphasize the sub-optimal reward systems as a second and co-occurring causality for ADHD (Sonuga-Barke, 2003). Dovis (2014) has shown that incentives significantly improve working memory performance of children with ADHD and that the intensity of the incentive determines the persistence of performance over time. Feedback-only was not enough for these children
to reach optimal performance. Within the studies presented throughout this thesis, children received daily small rewards at the end of each session (e.g. stickers or playtime) and a small present on a weekly basis. In order to investigate to what extend incentives during training could contribute to the effects of cognitive training, future studies should for example vary the amount of incentives between treatment conditions. Altogether, these specific and non-specific working mechanisms seem not exclusive of another rather it is likely that they interact with each other in determining the treatment outcomes. So far throughout this discussion we have focused on the potential working mechanisms and methodological factors that could contribute to the effects of cognitive training, now it is time to focus on the remaining part of Figure 1 and discuss the contribution of intervention specific features and individual differences.

**Intervention specific features**

Although intervention specific features were not directly examined in the current thesis, they will be briefly discussed below given the alleged impact of these factors on cognitive training outcomes. Throughout the cognitive training literature, training features vary greatly in terms of paradigms (e.g. single versus multiple targeted skills), intensity (frequency) and duration (dose) of training sessions and adjustment of task difficulty (Von Bastian & Oberauer, 2013). Regarding this first factor, the training paradigm, there still is no consensus of what works best for children with ADHD. Although it has been suggested that training just one single cognitive domain might not be sufficient to reach broad transfer (Moreau & Conway, 2014; Van Dongen-Boomsma et al., 2014), the effect of multiple executive function training also seems elusive so far (Dovis et al., 2015). It has been suggested though that the training paradigms are not in alignment with the neuropsychological deficits that are most impaired in children with ADHD (e.g. Gibson et al., 2011) and therefore future intervention designs should adequately target these broader range of neuropsychological deficits (Cortese et al., 2015; Orban et al., 2015; Rapport et al., 2013). Intensity and adaptivity have been assumed to be critical elements of working memory training (Klingberg, 2010). However, more recent research disputes the importance of these factors. For example, a
study of Von Bastian and Eschen (2015) found that there were no differences in training or transfer gains between training procedures that differed in task difficulty. In terms of intensity, a recent study of Mawjee and colleagues (2014) in adults with ADHD showed that a shortened-length version of CWMT (15 minutes) led to almost similar results as the standard-length version (45 minutes) even when motivation, engagement and expectancy of change were controlled for. Results from chapter 3 support this notion showing that quantitatively different exposure to working memory training (CWMT contained 90 trials while PAC contained 30 trials) led to quite similar results of transfer. Given that ADHD is a persistent developmental disorder, 25 sessions of training might not be enough to obtain its desired effects. And although CWMT offers an extended protocol (booster sessions), the potential benefit of these booster sessions has not been investigated so far.

In summary, the extent to which intervention specific features could contribute to cognitive training gains seems limited and needs more in-depth research. Alternatively, it has been suggested that transfer is most likely to be optimized if the activity takes place in a more ecologically valid setting (Moreau & Conway, 2014; Gathercole, 2014) and besides training EFs directly also addresses the emotional, social and physical needs (Diamond & Ling, 2015).

**Influence of individual differences**

Last but certainly not least, the last part of this discussion will focus on the individual differences in training gains, an area that until now was relatively unexplored within the field of cognitive training research for ADHD. In line with suggestions from others (Chacko et al., 2013; Shinaver et al., 2014), results from chapter 3 revealed that children with initial lower working memory skills and children who used medication benefitted more from CWMT. These effects did not generalize beyond the visual spatial span outcome measure, which is considered a trained task of CWMT. Interestingly, clinical variables were found to mainly influence far transfer outcome measures. Irrespective of type of training, children without a comorbid learning disability (LD) benefitted most in terms of word reading accuracy. Word reading accuracy
was also influenced by the subtype of ADHD, on the short term children with the ADHD combined (ADHD-C) subtype benefitted most from cognitive training in general. It should be noted though that both for the effect of comorbidity and subtype of ADHD, there were no differences between the subgroups on the long term which emphasizes the importance of including long term assessments of academic outcome measures. These findings might also explain why others (Egeland et al., 2013) found treatment effects on academic outcome measures as only children with the ADHD-C subtype were included with no mentioning of comorbid LDs.

The fact that both children with a learning disability and children with the ADHD Inattentive (ADHD-I) subtype could not benefit from training in terms of these academic outcome measures is not surprising. Just as children with a LD (Dehn, 2008), children with the ADHD-I subtype are more likely to suffer from poor working memory skills (Diamond, 2005). Additionally, a comorbid LD is more common in children with ADHD-I (Diamond, 2005) implying that there might have been in overlap in these children. Contrary to the academic outcome measures, children with the ADHD-I subtype benefitted most on the short term from training in terms of parent and teacher rated behavioral regulation problems. Additionally, within the group that followed CWMT, these children also benefitted most on the long term regarding teacher rated behavioral regulation and metacognition problems. This was a rather surprising though promising finding as studies that investigated the efficacy of CWMT in children with ADHD so far were not able to establish effects on teacher rated executive function behavior. The behavioral regulation scale of the BRIEF mainly contains ‘hot’ aspects of executive functioning (more associated with ventral and medial prefrontal cortex, e.g. inhibition and emotion regulation) while the metacognition scale mainly contains ‘cool’ aspects of executive functioning (more associated with the lateral prefrontal cortex, e.g. working memory and planning). We suspect that children with the ADHD-C benefitted less from cognitive training due to a more heterogeneous origin with both ‘cool’ and ‘hot’ executive function deficiencies. Children with the ADHD-C subtype are usually affected by both ‘cool’ and ‘hot’ executive function deficiencies in contrast to children with
ADHD-I how are mostly affected by ‘cool’ executive function deficiencies. Cool executive functions such as working memory are more likely to be elicited by relatively abstract decontextualized problems (Zelazo & Müller, 2011, p. 586) and can be associated with attention problems according to Castellanos and colleagues (2006). Hot executive functions can be described as the emotional problem solving executive functions (Zelazo & Müller, 2011) and are reflected in hyperactive/impulsivity symptoms (Castellanos et al., 2006). Future studies with larger sample sizes of different subtypes and well blinded assessments of executive function behavior are necessary to further investigate this potential beneficial effect for the ADHD-I subtype.

Regarding the PAC intervention, findings were somewhat contradicting for the initial cognitive abilities. Results from chapter 3 indicate that, just as for CWMT, children with initial lower verbal and visual spatial working memory skills in the PAC intervention group benefitted more in terms of an attention and visual spatial working memory task. This implicates a compensation effect which is usually found for process-based interventions, indicating that individuals with the lowest initial cognitive abilities probably benefit most because they have more room for improvement (Titz & Karbach, 2014; Karbach & Unger, 2014). The opposite was found in chapter 4, showing that children with higher initial attention and verbal working memory skills were more likely to benefit from training in terms of a working memory composite score. This implicates a magnification effect which has previously been observed for strategy based interventions indicating that individuals with high initial cognitive abilities might benefit most as more efficient cognitive resources make it easier to acquire and implement new strategies and abilities (Titz & Karbach, 2014; Karbach & Unger, 2014). Two factors should be taken into account when interpreting these contradicting results. First of all, the PAC intervention contained both a process-based and a strategy based training which makes it hard to disentangle the possibility of a compensation or magnification effect. Second, there was a methodological difference between the two studies in terms of how working memory was assessed as predictor (nominal versus continuous variable) and outcome measure (single construct versus composite score). Again, this highlights that one should always consider the way how transfer is
assessed when interpreting the results of cognitive training gains. Next to initial attention and working memory skills, there were several other factors found to influence the effects of PAC. For example, significant lower IQ scores were observed for children who did not clinically improve on working memory skills (non-responders) in chapter 4. In chapter 5, both age and IQ were found to predict initial working memory levels of the trained tasks within PAC. However, they were not a significant predictor of the actual improvement. It remains unclear how these factors exactly influence training gains. It has been suggested that it is not so much chronological age that is important but rather neurodevelopmental age (Rutledge et al., 2012) or stage of cognitive development (Jolles & Crone, 2012), i.e. age and earlier experience. Finally, chapter 4 disclosed additional important findings regarding who might, or actually who might not, benefit from cognitive training. Transfer for the non-responders of the PAC intervention, children with initial lower attention and verbal working memory skills, was limited to working memory tasks and parent rated questionnaires. A small group who additionally followed CWMT only improved on a visual spatial working memory task indicating that this is a group of children who cannot profit from cognitive training in its current form and are in dire need of adjusted treatment protocols.

Conclusively, results of current thesis have shown that several clinical and cognitive variables influence cognitive training transfer gains which warrants that future studies should shift towards a more individual approach of assessing training gains. Current findings might still be just the tip of the iceberg and individual differences in other variables such as prior treatment, motivation, personality, beliefs, biological factors deserve to be explored in future trials. A single-case experimental design (SCDE), with its repeated assessments during various phases of treatment, is a good example of a more individual approach for determining the therapeutically utility of cognitive training (e.g. Barlow, Nock & Hersen, 2009).
Summary and general discussion

Implications and directions for future research and practice

In terms of clinical implications, findings of current thesis show that cognitive interventions are not a quick fix solution of ADHD related problems. Rather it is an ambiguous and complex process that requires effort from the environment in which the effects do not follow a clear-cut path. Despite the fact that dropout rates were low, indicating that implementing cognitive interventions at school is feasible, the current thesis has shown that obtaining transfer to the classroom is not easy and that certain boundary conditions are crucial for optimizing the results of cognitive training. Coping with practical issues such as time scheduling of treatment sessions or a reasonable place to practice have been a major, but not insuperable, challenge in this study. To date, most cognitive interventions have been solely aimed at improving children’s executive functions directly. However, the current study has taught us that it is possibly even more important to actively involve the entire environment of the child. Although teachers are generally motivated to support these children within the classroom, in practice it is much harder to burden teachers with this task. Given the implementation of the law ‘Passend Onderwijs’ in the Netherlands (i.e. education that should fit), which makes schools obligated to provide adequate assistance for children who need extra care, the demand for similar interventions as PAC will continue to increase. An additional law that was recently implemented in the Netherlands, the transformation and transition of youth health care services to the local governments, heavily relies on the social network and requires an intensive collaboration from health care professionals, parents and teachers. Therefore, integrating the roles of all those involved should be the main target of future intervention designs, for example by encouraging parents and teachers to address the problems of the child with the same terminology both at home and at school. Finally, considering the financial investment of individual treatment and the large number of children that struggle with executive function deficiencies in the classroom, the feasibility of a group intervention should also be considered for future research.
The main important message for health care professionals is that cognitive training should be viewed as an adjunctive treatment of current guidelines, bearing in mind that it is not a “one size fits all” treatment. When the main aim is to improve executive function behavior at home or in school, clinicians should hold in mind that children with the ADHD-I subtype could profit most from training. Additionally, obtaining improvements in academic performance measures constitute a greater challenge for children with a comorbid learning disability, ADHD-I subtype or lower initial attentional and working memory skills. Clinicians should make a well balanced decision in terms of whether or which cognitive training might be suitable for a child. Next to evaluating the cognitive and functional impairments of children beforehand, it is also important that professionals discuss the expectations of parents and teachers and assess whether the environment can provide an optimal climate for training. The degree of commitment from parents, children, teachers and clinicians are all important to achieve the best possible outcome. Other factors that should be considered include timing within the academic year (e.g. not around curriculum based assessments periods) or unstable family conditions (e.g. divorcing parents).

Conclusion
Right from the start of this thesis, it was obvious that the study fulfilled the demand for implementable interventions in a school setting for children with EF related behavior and learning difficulties. Many professionals, teachers, parents and children cooperated enthusiastically and were positive about the applicability of PAC providing both children and teachers practical tools to work with within the classroom. This thesis started out with a fairly simple question namely: is cognitive training effective for children with ADHD? However, answering this question appeared to be anything but simple. When considering all factors discussed above, future research still faces many challenges before cognitive training meets the criteria as an evidence-based treatment for ADHD and can be added to the list of effective non-pharmacological interventions. Future research will, among other things, face challenges in terms of including adequate measures of transfer and adequate control groups. Nonetheless, we have made a good
start by showing that cognitive training, when implemented within the school setting, can effectively improve a fair amount of outcome measures. More importantly, the current thesis has shown that individual differences are crucial both in terms of clinical decision making and in determining the efficacy of cognitive training. This also encourages future researchers to assess training and transfer gains on a more individual level.