

Executive functions in children and adolescents

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Valorisation

The main aim of this thesis was to contribute to scientific knowledge about assessment and intervention of executive functions (EF) in children and adolescents. The meaning and significance of our findings for researchers and future studies have been described in the previous chapters. In the following valorisation paragraphs, we discuss the relevance as well as practical applications and implications of our findings in a broader societal context.

Relevance

EF is an umbrella term that incorporates many different cognitive functions, such as inhibitory control, working memory, cognitive flexibility, planning, organising, initiating, monitoring, reasoning, and strategy use ^[1, 2]. Behaviour associated with (un)successful EF in children's and adolescents' daily life becomes evident all throughout daily life. For example, a child being able to raise his/her hand and wait his/her turn when the teacher asked a question, shows signs of good inhibitory control. In contrast, a child who does not stay seated at the dinner table after repeated warnings from the parents may indicate unsuccessful inhibitory control. A teacher explaining to her pupils that they will start the day with some math exercises instead of grammar practice as they usually do, requires the children to be flexible in their thinking and acting. A father asking his adolescent daughter to first go to her room to get her jacket, then run to the basement to grab a shopping bag, and finally come to the kitchen, requires the daughter to use her working memory to remember the different steps of the instruction.

Previous studies have shown that EF are positively associated with children's and adolescents' mental and physical health, school functioning, participation, and quality of life ^[3-9]. Consequentially, difficulties with EF may have a significant negative impact on daily functioning. For example, being repeatedly scolded for not raising a hand in class or standing up from the dinner table may negatively affect a child's self-confidence. Not being able to remember multiple steps of an instruction may lead an adolescent to avoiding situations where these type of instructions are likely to occur, for example in after school activities.

Given the importance of EF for daily functioning, there is a pronounced interest in EF from educational and clinical professionals working with children and adolescents. In their daily work, these professionals may frequently use, or want to use, assessment tools to understand the level of EF of a child or adolescent in relation to other cognitive functions such as attention, as well as in relation to the child's or adolescent's behaviour, such as school functioning, participation or quality of life. In turn, interventions for EF may be used when a problem with EF was identified. A common cause of difficulties with EF in



children and adolescents is acquired brain injury ^[10-15]. In the Netherlands, 19.000 children and adolescents are diagnosed with acquired brain injury each year ^[16]. These children and adolescents may have EF deficits, potentially causing them to have difficulties waiting their turn in class, being flexible in their thinking when a schedule changes, or remembering instructions that entail multiple steps. It is therefore important that we can provide evidence-based recommendations on how to assess EF and how to approach EF difficulties with *interventions*. In this thesis, we offer insights into both of these aspects regarding EF in children and adolescents.

In terms of *EF assessment*, findings of the studies presented in this thesis indicate that, at least in young children, the use of EF may be specific to the task or the context of the behaviour. This means that children may employ their EF when approaching one task, but not when performing another task. Professionals making use of EF assessment should be aware that outcomes of various tasks, supposedly tapping into the same or similar EF processes, might differ. For example, even though the verbal fluency task and the design fluency task are often thought to be each other's verbal respectively non-verbal equivalent, children may not rely on the same (EF) processes to perform both of these tasks. Young children may use EF such as monitoring and cognitive flexibility in a context that is familiar to them, for example, when trying to name animals as is the case in the verbal fluency task. In contrast, in an unfamiliar, more abstract context, for example when creating abstract designs in the design fluency task, children may not employ the same EF. Moreover, the context specificity of EF may not only apply to EF tasks, but also to the use of EF in daily life. For example, a young child who is able to organize his or her desk drawer at school might not necessarily be able to organize also his or her toys at home. This may potentially be caused by the inability of a (young) child to transfer the use of EF in one situation to another context.

In terms of *EF interventions*, educational and clinical professionals may find it relevant to know that wide-ranging improvements in EF or in associated daily functioning cannot be easily achieved by trying to improve a specific EF in an isolated context. The use of popular brain training programs provides an illustrative example. These programs often propose that repeated playing of a game to train a specific EF, such as working memory, will lead to improvements in working memory, but also for example in school functioning and daily behaviour. Unfortunately, there is increasing evidence that these training programs only lead to very specific improvements in the trained (EF) tasks, but not in other areas of functioning. To improve a wider range of functioning, children and adolescents may not only need repeated practice but also additional support in the use of EF in various contexts. Before initiating an EF intervention, educational and clinical professionals may thus want to consider the ultimate goal of the intervention and to adapt the intervention to that goal. For example, if the intervention goal is to help an adolescent to improve the ability to

follow instructions in class, the intervention may consist of practicing attentional control and working memory, but also give clear directions and strategies on how to use these skills in the classroom context. Explicit strategy training, as we developed and described in chapter 7 of this thesis, may provide a useful tools for this purpose.

Target groups

The knowledge generated with the studies of this thesis may be of interest to a large and diverse audience. In our studies, we investigated EF in children and adolescents with and without acquired brain injury.

Educational professionals working with children and adolescents with and without acquired brain injury may gain new knowledge about EF from our studies. Educational professionals can include classroom teachers, remedial teachers and mentors. The results of the studies presented in this thesis may inspire them to pay more attention to EF that potentially underlie school functioning and classroom behaviour of their pupils. Moreover, they may benefit from the new insights into EF interventions, described in chapter 4 and 6, suggesting that the context provided in an intervention may play a role in generalization of EF improvement. When bringing EF interventions into their daily teaching, they may include clear examples of contexts that are relevant for the child or adolescent taking part in the intervention.

In a clinical context, children and adolescents with acquired brain injury are often treated by a multidisciplinary team consisting of rehabilitation physicians, neuropsychologists, occupational therapists and psychologists. *Neuropsychologists and occupational therapists* may use findings of our review described in chapter 6 to select an appropriate cognitive intervention. Specifically, intervention purely consisting of repeatedly practicing a task (such as the brain training programs mentioned above) may not be useful to achieve meaningful changes in daily functioning, as mentioned above. In contrast, interventions based on metacognition or strategy use training have the potential to improve children's and adolescent's daily behaviour, and, when combined with repeated cognitive practice, may be able to improve daily cognitive functioning. Clinical professionals working with children and adolescents with acquired brain injury are currently already applying our new intervention described in chapter 7 in the context of our ongoing trial.

A variety of clinical professionals may benefit from the overview of participation instruments we present in the review in chapter 8. The results of that review may support the selection of instruments to assess participation in children and adolescents with acquired brain injury. On the one hand, we describe how the participation instruments align with contemporary conceptualizations of participation. On the other hand, we provide an overview of their psychometric properties, which are essential to consider for valid and reliable assessment. The Child and Adolescent Scale of Participation ^[17, 18] is currently the



only participation instrument available that aligns with current participation definition and has been examined for its psychometric properties in the Netherlands. However, many other participation instruments are available. When selecting an instrument to measure participation in children and adolescents with acquired brain injury, clinical professionals should be aware of the advantages and disadvantages of these various instruments.

A final potential target group for the results of our study are *parents and caregivers*. Some of our studies show that level of parental education, which may be a proxy for parent-child interaction, can influence EF, at least in young children. Awareness of their own influence on their child's EF may facilitate parents' and caregivers' understanding of children's behaviour and functioning. For parents or caregivers of a child or adolescent with acquired brain injury, it may be relevant to know that consequences of brain injury are not always apparent immediately after the injury, making long-term vigilance for potential difficulties necessary (chapter 5). Moreover, the insight provided by chapter 6, that merely practicing EF by repeating EF tasks may not yield wide-ranging effects, may dampen enthusiasm regarding popular computerized brain training programs and thereby protect parents from unnecessary costs. As an alternative, they may consider intervention options that include explicit strategy instruction to support generalization of EF improvement to daily life.

Activities and products

The work of a researcher is not complete once research data have been analysed and published. An essential task of a researcher should be to make efforts to clarify theoretical and practical implications, to disseminate the findings, and, if applicable, assist those who may try to develop or apply products, services and activities based on these findings.

Findings of this thesis have been presented at multiple *national and international conferences*. Many of these conferences are also attended by clinical practitioners and educational professionals. Moreover, results have also been discussed at clinical symposia and in expert meetings in clinical settings, such as rehabilitation centres. In the Netherlands, we are strongly involved in a network of professionals working with children and adolescents with acquired brain injury, facilitating the dissemination of our findings and products. To communicate new insights with the general public, our research on cognitive interventions for children and adolescents was presented in a *newspaper article* in De Limburger and was discussed in the *local radio show* RTV Maastricht Het Beleg.

Our work has led to several concrete products. To bridge the gap between our scientific findings and educational practice, we are currently preparing an evidence-based *brochure about EF for educational professionals*. This brochure includes a description of EF and their developmental pathways, clear examples of EF behaviour, as well as tips and suggestions on how to approach EF difficulties in children and adolescents. For clinical professionals

working with children and adolescents with acquired brain injury, we created an overview of available cognitive interventions and their effectiveness (chapter 6), which was published in an international peer-reviewed journal. We also made an overview of instruments to assess participation of these children and adolescents (chapter 8). By presenting these overviews at clinical symposia and to interested professionals, we aim to assist professionals in using the overviews in their daily clinical practice. Finally, we developed a new cognitive intervention for children and adolescents with acquired brain injury. A detailed description of this intervention is provided in chapter 7 of this thesis.

Innovation

In terms of EF assessment, our studies suggest that studying EF processes underlying broader cognitive task performance can provide insight in young children's EF. As a next step, it should be examined how these processes are associated to daily life functioning, such as school performance. If outcomes from EF process assessment and daily life functioning are found to be associated, process measures may form an interesting addition to current clinical and/or educational assessment.

In terms of EF intervention, current available interventions for children and adolescents, both with and without acquired brain injury, are mostly focused on trying to *train* EF. Specifically, they underlie the assumption that by practicing certain EF tasks, EF performance will improve on those tasks, but also on other tasks and in daily life. Unfortunately, changes in other tasks or daily life are only minimal. In our review in chapter 6, we therefore made an effort to disentangle the effective components of cognitive interventions for children and adolescents with acquired brain injury. There are currently no recommended cognitive interventions for these children and adolescents. Our new intervention meets a current need for new, protocolled intervention. In the intervention, we apply state of the art knowledge about effectiveness of intervention components by combining EF practice with strategy instruction.

Implementation

To disseminate our findings among educational professionals, we are currently preparing an implementation plan for the brochure described above. We aim to distribute the brochure across educational professionals throughout the south of the Netherlands. Moreover, the brochure will also become available online.

The new intervention described in chapter 7 is currently being investigated for its effectiveness. The intervention protocol is currently already available at eight rehabilitation centres and specialized school across the Netherlands, where the intervention is currently being examined for effectiveness. The study is expected to be completed in July 2020, after which the collected data will be analysed. If the intervention proves to be effective in improving



children's and adolescents' EF and/or functioning in other life areas, the intervention will be made available for use in rehabilitation centres and specialized schools across the Netherlands. When designing the study into the effectiveness of the new intervention, we took into account the potential for future implementation. Health care providers are limited in the time they can use to provide care to a child or adolescent due to constraints in, for example, health insurance coverage. A new intervention would therefore mostly be used *instead of* another intervention, rather than *in addition to* another intervention. Our new intervention is being investigated as an alternative to the care currently provided by the rehabilitation centre or school. If found to be effective, the intervention can therefore be easily and without additional costs be implemented in daily clinical practice.

We developed the intervention specifically for children and adolescents with acquired brain injury. However, difficulties with EF also occur in other populations, such as children and adolescents with learning disabilities or with attention deficit hyperactivity disorder. Moreover, a recent review of cognitive interventions for these populations have indicated that, similar to results found in our review in chapter 6, explicit strategy instruction is a promising component ^[19]. Our intervention may therefore be of interest for professionals working with other populations than children and adolescents with acquired brain injury. If needed, the intervention can also be translated for use in other countries.