Determinants of the neuropsychological development of schoolchildren and adolescents

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Concluding Remarks

The studies described in this thesis aimed to investigate determinants to individual differences in the neuropsychological development of preadolescents and adolescents aged 7–19 years. The determinants these studies have focused on were sex and parental education. The influence of both determinants was evaluated on the development of neuropsychological abilities that are important for learning at school. These neuropsychological abilities included various executive functions and self-regulatory skills. It was a special aim to gain insight into the perceptions that teachers (chapters 2 and 4) and parents (chapter 2) have about the executive functions and self-regulatory skills of the student/child, as well as to study the perceptions of (pre)adolescents themselves (chapters 6 and 7). The influence of sex and parental education was also evaluated on the ability to learn pictorial information (chapter 3), and sex differences were investigated on mental rotation ability (chapter 5). Three large-scale cross-sectional studies were conducted to investigate these aims.

Two important conclusions can be drawn based on the results of these studies: (1) There are substantial sex differences in the neuropsychological development of preadolescents and adolescents and these differences vary with age, and (2) there are differences in the neuropsychological abilities of children from lower and higher educated parents. This chapter reflects on these two main conclusions, discusses practical implications and interventions, and provides suggestions for future research.

Sex differences in neuropsychological abilities

Four chapters in this thesis described sex differences in neuropsychological abilities. The research described in chapter 2 focused on sex differences in teacher-perceived executive functions and self-regulation skills of preadolescents and adolescents aged 9–12 years. The research described in chapter 6 focused on sex differences in self-perceived executive functions and self-regulation skills in participants aged 10–19-year. Sex differences were also described in chapter 3 on the ability to learn pictorial information in preadolescents and adolescents aged 8–12 years. Finally, chapter 5 described sex differences on mental rotation ability in participants aged 7-12 years.

Sex differences in observed versus self-perceived functioning

Teachers observed sex differences in executive functions and self-regulatory skills (see chapter 2). Teachers observed that boys have more difficulties with sustaining attention in the classroom and with planning their schoolwork than girls. They also observed that boys have more difficulties in suppressing impulsive behavior and reflecting on their behavior than girls. These findings indicate that the development of executive functions and self-regulatory skills is lagging behind in boys compared to girls at the age investigated: 8–12 years. Delays in the development of executive functions and self-regulatory skills may hinder young adolescent boys to successfully engage in academic performance. At school, students need to neglect distracting information and keep attention for longer periods of time, otherwise they may miss important information taught in the classroom. Students also need to control impulsive behaviors to stay focused in class. For homework to be completed in time, students need good planning abilities. As boys have more difficulties with sustaining attention in the classroom and with planning and completing their homework than girls, they may gather less knowledge and develop fewer skills at school. Consequently, grade retention, streaming down to lower educational tracks and early school leave are more common among adolescent boys than girls (see OECD 2015). The discrepancy in school performance of boys and girls may thus be attributed to differences in the pace at which their executive functions and self-regulatory skills develop.

There was a notable difference between the self-perception of boys and the judgements of their teachers. Unlike teachers, boys did not report more difficulties in their executive functioning and self-regulation than girls at the age of 10–13 years (see chapter 6). It could be that at the age of 10–13 years, boys and girls cannot judge their behavior because self-regulatory skills and self-insight are in a process of maturation at this age. Both abilities continue to mature into at least early adulthood (Anderson, 2002; Diamond, 2013).

Consequently, the self-insight of young adolescent boys and girls may be poor; they evaluate their behavior based on what they have heard from their parents or teachers. The lack of self-insight in 10-13-year-old children may thus explain why boys and girls evaluated their executive functions and self-regulation equally in this age-group.

At the age of 13–17 years, on the other hand, boys did more often than girls report that they experience difficulties with self-regulation. Boys reported that they more often experience problems with suppressing impulses, goal-directed behaviors and paying attention. In contrast to the evaluations of teachers, self-reports give information on the executive functioning and self-regulation as adolescents perceive them in a social context. The behavior of adolescents is influenced by social factors derived from home, school, their peers and other domains. Especially the peer group plays an important role in adolescent development. Adolescents spend increasing time with peers. They learn new behaviors and attitudes by observing and imitating their peers. It is notable that adolescents especially engage in risky behavioral acts when surrounded by their peers (see the quotation of a teenager in Box 2). It is therefore interesting to investigate how adolescents perceive their executive functions and self-regulatory skills in such social contexts. This seems a valuable approach as we found that when adolescents aged 13–17 years evaluated their self-regulatory skills lower, they indicated that they were more likely to participate in risky and anti-social behaviors (see chapter 7). It seems logical that the lower adolescents evaluate their self-regulatory abilities, the more likely they are to actually participate in anti-social behavior. The results in this thesis do not allow further elaboration on this association. It is, however, clear that studying self-perceptions of adolescents in terms of executive functions and self-regulation is a valuable new approach to gain insight into the intricate processes underlying adolescent behavior. It may have relevant applications for interventions too as it suggests that adolescent behaviors can be changed if executive functions and self-regulation improve.

Box 2. The influence of peers on adolescent behavior

"It seems like people accept you more if you're, like, a dangerous driver or something. If there is a line of cars going down the road and the other lane is clear and you pass eight cars at once, everybody likes that...
If my friends are with me in the car, or if there are a lot of people in the line, I would do it, but if I'm by myself and I didn't know anybody, then I wouldn't do it. That's no fun."

— Anonymous teenager, as quoted in The Culture of Adolescent Risk-Taking (Lightfoot, 1997, p. 10)

Sex differences in pictorial learning

Other sex differences were reported on the ability to learn pictorial information in 8-12-year-old preadolescents and adolescents (see chapter 3). It is of special interest that girls only outperformed boys when information was presented for the first time, i.e., on the first trial of a multi-trial learning task. Boys and girls had a similar score on the second and third trial of this task. This indicates that boys and girls do not differ in their learning abilities per se. It is more likely that they differ in abilities underlying their learning performance, such as in their executive functions, learning strategies or attention. For instance, differences in executive functions and self-regulatory skills between boys and girls (as discussed in chapter 2) indicate that boys have suffered more than girls from the distraction that goes with assessment and explanations in a classroom setting. This may especially be the case when a learning tasks is presented for the first time: It is plausible that especially boys did not pay sufficient attention during task-instruction and therefore miss important clues as to evaluating the question *"what do they expect from me and what could be the best approach to take?".* Teachers should therefore provide more support and guidance to boys when learning tasks are presented for the first time. Another consequence of sex differences in executive functions and self-regulatory skills is that boys and girls use other learning strategies. Dekker and colleagues (2013) reported that boys more often endorsed work-avoidant approach goals than girls. Girls, on the other hand, more often endorsed mastery and performance-approach goals. Mastery and performance-approach goals were related to better executive functions and self-regulatory skills, and consequently higher academic achievement than the avoidant goal (Dekker et al., 2013). It thus appears that sex differences in executive functions and self-regulatory skills account for differences between boys and girls in their learning strategies. This affects their academic performance. This is a vision with great potential as it indicates that learning performance of boys may improve if executive functions and self-regulatory skills improve. Neuropsychological interventions that focus on enhancing the executive functions and self-regulation skills of young adolescent boys may therefore offer a valuable solution for sex differences in academic achievement during adolescence.

Sex differences in spatial information processing

Finally, sex differences were reported on a mental rotation task in 7-to 9-year-old preadolescents. Boys outperformed girls. A substantial body of research showed that experiences and activities can facilitate the development of spatial abilities. For instance, activities which are usually evaluated as being male-typical can substantially improve spatial abilities and performance. These activities include playing with construction toys or action video games (Miller & Halpern, 2014; Uttal et al., 2013a; Uttal et al., 2013b). It has even been shown that these activities cause changes in cortical thickness and sex-differentiated patterns

of brain activation (Haier et al., 2009; Jaušovec & Jaušovec, 2012). This finding is promising as it suggests that the development of spatial abilities may improve by experiences and training. This is an important finding as it indicates that lower performance on spatial skills in girls is - at least partly - due to nurture (i.e., environmental support). Girls would benefit from being provided with spatial toys in order to stimulate the development of their mental rotation abilities. Stimulating these abilities in girls is of special interest when looking at their underrepresentation as compared to boys in science, technology, engineering, and mathematics.

Conclusions and interventions

As we continue to understand learning processes, we know that not only cognitive abilities are important for learning outcomes. Self-regulatory skills and neuropsychological abilities, motivation and attitude towards school are important as well. The teenage years are a crucial time for developing self-regulatory skills and for putting them into practice. Secondary schooling demands more independence, initiative, and self-reliance, especially when students are expected to work by themselves on assignments that take a longer time to complete. An example is a term paper that is due at the end of a semester. In primary grades, teachers and parents often help students to stay focused, especially those who have weaker self-control. This support wanes as students get older, because children and teens gain experience and become more independent (Steinberg, 2014). Rather than only being content-driven, education should also focus on the learning adolescent in a social setting, and to his personal growth (Jolles, 2016).

Adolescence is a key period to develop neuropsychological abilities such as self-regulatory skills. The brain systems that govern this capacity remain highly plastic throughout adolescence (e.g., Giedd, 2008; Lenroot & Giedd, 2011; Steinberg, 2014, Wierenga et al., 2017). School should, therefore, implement intervention programs in their curricula that stimulate their students' executive functions and self-regulatory skills. These types of interventions will have value apart from interventions directed at stimulating motivation, metacognition and the attitude towards school. An example of a possible approach in this regard, is the educational intervention BrainSquare (in Dutch: BreinPlein) made by the Center for Brain & Learning Amsterdam. This intervention was developed and tested in the school environment in close collaboration with primary schools. BrainSquare provides materials and tasks that stimulate the development of spatial abilities and spatial reasoning, and also problem solving, sustaining attention, planning abilities, and other executive functions and self-regulatory skills. In addition, BainSquare aims to promote school motivation and attitude. The materials and tasks can be beneficial for girls, as they challenge spatial abilities and spatial reasoning. They can also be beneficial for boys because they allow them to gain experience with unfamiliar tasks.

Moreover, boys practice with sustaining attention for longer periods of time and suppressing impulsive behaviors. Extended information on BrainSquare is provided in the appendix of this thesis (Centre for Brain & Learning Amsterdam, see www.hersenenenleren.nl and www.breinplein.nl).

A final note on sex differences: Sex differences are influenced by age

Taking the findings of chapter 2, 3, 5 and 6 together, it appears that there are substantial sex differences on various neuropsychological abilities. The age at which sex differences were most pronounced depended on the ability investigated. An implication of this age-specificity of sex differences in self-perceived executive functions and self-regulatory skills is that adolescents aged 10-13-year-old need other interventions to stimulate their neuropsychological development than 14-17-year-old adolescents. At the age of 10-13 years, boys do not experience difficulties with their executive functioning and self-regulation yet, while teachers do already observe them (see chapters 2 and 6). This requires another kind of intervention than for 14-17-year-old adolescent boys, who do experience difficulties with their executive functions and self-regulatory skills (see chapter 6). Younger adolescent boys can be provided with interventions such as BrainSquare. Older adolescents, on the other hand, can be expected to benefit more from a neuropsychological intervention based on psycho-education, skills training and self-evaluation training. For instance, psycho-education may explain to adolescents that the difficulties they experience will be temporary in nature. This may change their expectations of what they can achieve in school. Similarly, knowing that brain development can be stimulated positively influences their effort and school motivation (Blackwell, Trzesniewski, & Dweck, 2007). Moreover, teaching adolescents' strategies to plan and organize their school work and to remove external distracting stimuli which are potentially distracting, and teaching them to suppress impulses can help them to exert more control over their learning process. Psycho-education thus aims to provide information about causes, consequences and coping strategies. An example of such an educational intervention developed by the Center for Brain & Learning Amsterdam is "Brain Lessons." This intervention aims to provide knowledge to students about their brain and its involvement in learning. It also focuses on the improvement of self-evaluation skills with respect to classroom behavior and homework attitudes (Dekker & Jolles, 2015). Thus, other interventions are needed to improve the neuropsychological development of younger and older adolescent boys because they perceive their behavior and behavioral difficulties differently.

Another implication based on the finding that sex differences are presented at specific ages, is the need to investigate sex differences in neuropsychological abilities in samples with narrow age-ranges. If sex differences were investigated in the total study population (including individuals in early, middle and late adolescence), an actual sex difference which exists at a

particular age will be reduced by the smaller differences at earlier and later ages. As a result, the average difference between boys and girls in the total group decreases. This does not do justice to the large differences in behavior, cognition and academic performance in boys versus girls, especially in particular periods of adolescence. It is, therefore, recommended for future research to investigate the issue of sex differences in neuropsychological abilities in study samples with narrow age-ranges.

A final important note with respect to sex differences in the neuropsychological development is that we should avoid stereotypes about boys' (and also girls') academic performance. Previous research showed that test performance was hindered if boys were told that they are academically inferior to girls (Hartley & Sutton, 2013). Thus, we should not portray them as academic underachievers. Neuropsychological abilities and learning performance are not fixed: They can improve with practice and motivation. Focusing on development and individual differences emphasizes each individual's possibility to grow over time. Such an approach can counteract prior negative sex stereotypes about boys' academic performance (Hartley & Sutton, 2013).

The role of parental education to neuropsychological development

Two chapters in this thesis examined differences in the neuropsychological development of children from higher and lower educated families. In chapters 2 and 4, differences between children of higher and lower educated parents in teacher-perceived executive functioning and self-regulation were discussed, in respectively 9–12 and 8–12-year–old preadolescents and adolescents. Moreover, differences between children of higher and lower educated parents in pictorial learning ability were discussed in chapter 3.

Children from higher educated parents outperform those from lower educated parents

Teachers observed differences in the executive functions and self-regulatory skills between children of lower and higher educated parents (see chapters 2 and 4). Teachers observed more difficulties with planning schoolwork and organizing thoughts and behaviors in children of lower educated parents than in children of higher educated parents. Delays in the development of planning and organization skills may hinder children of lower educated parents to successfully engage in academic performance. This notion is substantiated by the finding that children of lower educated parents were outperformed by children of higher educated parents on a three-trial pictorial learning task. Notably, this was only the case when information was presented for the first time, i.e., on the first trial of a multi-trial learning test (see chapter 3). This indicates that children of more highly educated parents may be better in processing newly

presented tasks and unfamiliar procedures. Differences in the neuropsychological development of children from higher and lower educated parents may thus contribute to differences in learning performance.

A possible explanation is that children of more highly educated parents have more experience with new tasks and with figuring out their procedures. Higher educated parents generally have more money to provide their children with new books and a greater diversity of games and playing materials (e.g., Rindermann & Baumeister, 2015). Books, games and playing materials stimulate the development of their children's skills and neuropsychological functions. They are thereby of profit for their schoolwork (see also CDC, 2014). Reading books stimulates mental imagery and eventually enable the child to concentrate on the content of the book and to sustain attention. In addition, playing games teaches children to figure out task-instructions step by step. Children learn to hold complicated moves in mind, plan moves ahead, and then adjust plans—both in response to imagined outcomes and to the moves of opponents (CDC, 2014). Children also learn to sustain attention and to deal with frustrations. Higher educated parents also generally have more money to spend for cultural activities, such as a visit to the museum. Children gather knowledge over a broader domain when they visit cultural activities such as going to museums. The also learn to make a planning while going on excursions: "*when and what time are we going, how do wo go and what should I bring with me?".* All of these experiences are advantageous when provided with an unfamiliar task at school, such as an exam. Children of lower educated parents or children who grow up in poverty gain fewer experiences than children who grow up in higher educated families or in wealth.

There are neuroimaging studies which have reported on the consequences of growing up in a poor and lower educated family versus growing up in a wealthy and higher educated family. These studies revealed clear differences in brain regions involved in the development of language, memory, and reasoning skills between children growing up in wealthy families and in poor families (Noble et al., 2015). In short, the brain is the product of both biological factors and experiences. Children of lower educated families gain fewer experiences than children of higher educated families. This results in a lag in brain maturation between these children. This maturational lag can be reduced by substantial environmental stimulation, inspiration and support (Haier et al., 2009; Jaušovec & Jaušovec, 2012; Miller & Halpern, 2014; Uttal et al., 2013a; Uttal et al., 2013b). As most disadvantaged families cannot provide the required stimuli and experiences to their children, the effects of poverty often cause permanent damage to the neuropsychological development of children.

A possible consequence of the lag in neuropsychological development of children from lower educated families is that teachers advise these children to go to lower educational levels at secondary school compared to children of higher educated parents. This is even the case when both children have equal IQ's (see Inspection of education, 2015). Teachers observe that

children of lower educated parents have more difficulties organizing their school work, sustaining attention in the classroom, and suppressing their impulsive behaviors than children of higher educated parents. Teachers may therefore expect that children of lower educated parents will experience more problems at higher educational levels where learning materials are more complex. Teachers may decide to advice these children to go to lower educational levels and thereby potentially misjudge their growth potential.

Implications and educational interventions to fuel neuropsychological development

School can play a substantial role in providing stimuli and experiences that stimulate brain maturation of children growing up in disadvantages families. By implanting educational interventions such as BrainSquare into their regular curriculum, they provide children of disadvantaged families with the opportunity to gain practice and experiences with tasks and materials that stimulate the development of their students' neuropsychological abilities.

To provide children of disadvantages families with the right tools and materials, future research should more precisely determine the differences between the learning environments that higher and lower educated parents provide to their children. This enables us to provide children of lower educated parents or those who grow up in poverty with the missing stimuli and experiences that children of higher educated families and wealthy families do gain. This is needed to create equal developmental and educational opportunities for children from lower and higher educated families.

Lessons to learn for teachers and parents

Lessons for teachers

The role of the teachers is not confined to providing new knowledge to their students. Rather, they also have an important role in stimulating the development of neuropsychological abilities and self-regulatory skills. These abilities and skills allow students to learn more effectively. This results in higher educational achievement (see also OECD, 2014). Psycho-education can help to change the attitude of teachers towards learning. With the aid of psycho-education, teachers can learn more about psychological development, the brain and neuropsychological abilities in adolescence. Teachers can be supplied with information about brain processes underlying learning and memory formation. This may help teachers to improve classroom practices and find better routes to innovate the educational process (Dommett, Devonshire, Plateau, Westwell, & Greenfield, 2011). For example, when teachers understand that learning involves the formation of strong connections within networks of neurons in the brain, and that brain connections are strengthened by rehearsal, they may take more efforts to rehearse frequently

in their lessons. Moreover, teachers should know that neuropsychological abilities and brain plasticity continue to mature until at least the early 20s, and that maturational processes can even be extended up into later ages by environmental stimulation. Knowledge about self-regulatory skills and their development allows teachers to engage proactive in the neuropsychological development of their students.

To monitor the neuropsychological development of adolescents, teachers can use checklists and screening instruments that have their origins in behavioral and cognitive sciences. These instruments can provide teachers with tools to structure their observations and to articulate (i.e. give words to) them. For instance, teachers oversee the trajectory of the development of the student in the school setting. They observe how students improve their planning skills and their ability to suppress impulsive behaviors. They also observe how students learn to work independently on school tasks and how they develop new interests. Teachers can monitor these changes with the use of screening instruments and checklists. These screening instruments and checklists provide the teacher with a direction to what abilities they should pay attention to. This allows teachers to detect a student's weaknesses in a structured way, and to come up with solutions. For instance, a checklist on planning abilities can indicate that the adolescent has difficulties with organizing and planning his/her homework. Teachers can provide these students with planning strategies. Screening tools can also be beneficial to students with well-developed executive functions. Teachers can increase the complexity of assignments given to these students to challenge their executive functions and self-regulatory skills even more. Neuropsychological checklists and screening instruments can thus be valuable tools for educational practices.

Lessons for parents

Parents can benefit from knowledge about the neuropsychological development of their children in an analogous way. Better insights into the psychological and neuropsychological development could improve their understanding of typical adolescent behavior such as risk-taking. Similarly, knowing that brain maturation can be stimulated by environmental stimulation and experiences may trigger parents to engage in activities that promote brain maturation (Blackwell et al., 2007). Parents should therefore be provided with information about activities that stimulate the neuropsychological development of their children. For instance, building with construction materials requires children to make a mental three-dimensional representation of a construction. Children practice spatial skills and spatial reasoning while rotating the construction into their minds. The also learn to make a behavioral planning: *"where should I start, and what is the next step?"* Children learn to think logically and to solve problems. They also learn to cope with frustrations when the construction which they have made collapses. Building with construction materials thus stimulates the development of

various neuropsychological abilities that are important for performance at school (see also the appendix of this thesis). Moreover, there are many daily life activities that appeal to neuropsychological abilities. Consider, for example, the executive functions and self-regulatory skills needed when going to the supermarket for groceries. Children need to plan when to go, they make mental representation of the roads to the supermarket and decide which road they are going to take. While paying attention to the traffic on the way to the supermarket, they need to remember all groceries. Sometimes, children even need to suppress impulsive behaviors while suppressing the urge to buy candy instead of the groceries their mum asked for, or to go with a friend they happen to come across. Parents should be provided with information about how to organize such daily life routines to stimulate the development of their child's executive functions and self-regulatory skills.

A final note

In sum, each preadolescent and adolescent has the right to develop and unfold his/her full educational potential. It is therefore important to know the determinants which contribute to individual differences in neuropsychological development. This provides information for educational practice and pedagogical interventions. The studies in this thesis revealed two determinants that contribute to individual differences in processes underlying learning performance. These determinants are sex and parental education. Both determinants influence executive functions, pictorial learning and mental rotation performance. The adolescent was studied considering information of the adolescents themselves, as well as information about their functioning as perceived by teachers at school, and by parents at home. In this way, neuropsychology builds a bridge between three different dimensions of the complex behavior, cognitive functioning and attitudes of the adolescent. Neuropsychology – which has its origins in clinical practice – has the potency to contribute to improving our understanding about normal neuropsychological development in preadolescence and adolescence, both in the home situation and in relation to achievement in the school setting.

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