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1.

**GENERAL
INTRODUCTION**

Children differ in their ability to learn the subject material that is taught at school. Some master basic skills and pick up knowledge easily while others struggle to keep up with their peers. Educational achievement in children has several facets: it can be defined as the performance at school as assessed by the teacher, as the extent to which children achieve the educational goals corresponding to their grade level, or as the outcome on a standardized test at a particular age, such as the Dutch educational achievement test administered in the last grade of primary school (Cito, 2002). Even children of similar age, attending the same school and taught by the same teacher differ greatly in their performance at school. Low educational achievement is an important predictor of continued low achievement, school dropout, delinquency (Moilanen, Shaw & Maxwell, 2010) and of numerous other outcomes later in life, including lower earning (Julian & Kominski, 2011) and lower well-being (Mackenbach et al., 1997).

Numerous studies have also found a negative effect of attention deficit hyperactivity disorder (ADHD) and oppositional defiant disorder (ODD) on educational achievement (Greene et al., 2002; Polderman et al., 2010). Children with ADHD have difficulties with both inattention and hyperactivity or impulsiveness that interfere with daily functioning. ODD is characterized by hostile and defiant behavior towards figures with authority, going beyond normal childhood behavior (American Psychiatric Association, 2000). At school, children with ADHD have, for example, difficulty remaining in their seats and children with ODD often argue with their teachers. Children with ADHD and ODD receive lower grades and are more often referred to specialized education (Biederman et al., 1996; Greene et al., 2002).

The overarching aim of this thesis is to increase knowledge on the causes of individual differences in educational achievement and problem behavior of Dutch children attending primary school. This aim is to be achieved through a series of studies that are carried out based on data of young twins and their siblings. School performance was assessed by their teachers with the Teacher Report Form (TRF) (Achenbach, 1991), educational achievement was measured with objective standardized tests, pupil monitoring tests (Cito, 2014) for all grades and a national educational achievement test administered in the final grade (Cito, 2002). Problem behavior was rated by teachers with the short Conners' Teacher Rating Scales - Revised (CTRS-R) and by mothers with the short Conners' Parent Rating Scales - Revised (CPRS-R) (Conners et al., 1998; Conners, 2001). The objectives were threefold. First, to investigate the influence of twin specific risk factors on educational achievement by examining differences in educational achievement between twins and their non-twin siblings. Second, to determine the causes of individual differences in

educational achievement and behavioral problems in primary school aged children by applying the classical twin design, which compares the resemblance in mono- and dizygotic twin pairs (Plomin et al., 2008). Third, to test the association between behavioral problems and educational achievement by using molecular genetic approaches and causality models.

Chapter 2 looks at the influence of several twin specific risk factors on school performance, the proficiency of a child as rated by their teacher in arithmetic, language, reading and physical education at the beginning of primary school and the educational achievement test in the final grade. The studied risk factors are not unique to twins, except for zygosity, but show a higher prevalence in twins than in singletons. The school performance of twins is compared to that of their non-twin siblings in a within-family design, thereby taking into account confounding of multiple demographic characteristics.

Chapter 3 describes the influence of an environmental factor, a same-gender teacher versus a different gender teacher, on school performance, educational achievement, and ADHD behavior of 12-year-old children in two genetically sensitive designs using monozygotic twin pairs who are discordant for the gender of their teacher(s) and dizygotic twin pairs of opposite-sex who are concordant for the gender of their teacher(s). Differences within these twin pairs are likely to be ascribed to the influence of the gender of the teacher, since (part of) their genotype, family background, social economic status, and multiple other characteristics of the twins are similar and thus controlled for. This chapter aims to contribute to the ongoing discussion in society as to whether children, especially boys, might be disadvantaged by the feminization of primary education.

Chapter 4 reports on the influence of genetic and environmental effects on educational achievement across the primary school years. Data on educational achievement were collected from teachers by asking them to send in a student report with the results of pupil monitoring tests assessing arithmetic, reading, reading comprehension and spelling from grades 1 to 6 (Cito, 2014). In the Netherlands, in addition to the pupil monitoring tests, a standardized educational achievement test is administered in the final grade. Possible gender differences in the etiology of educational achievement are also explored.

Chapter 5 provides a comprehensive review of the existing twin studies on educational achievement in primary school children (6-13 years) assessed in unselected genetically informative samples. To enhance statistical power and to estimate heritability across multiple data sets from the world literature, meta-analyses of twin correlations were performed for scores in several educational domains, i.e. reading, reading comprehension, mathematics and spelling. It was

tested whether there were differences in the heritability of educational achievement between countries.

Chapter 6 looks at the extent to which individual differences in ODD and ADHD behavior are influenced by genetic effects and determines the moderation of the heritability by classroom sharing, gender of the student and gender of the teacher. ODD and ADHD behavior were assessed by the four scales of the CTRS-R. First, a series of models were investigated to test for measurement invariance (MI), across gender of the student and teacher for the four CTRS-R scales. MI means that children with the same (unobserved) ADHD or ODD vulnerability have the same probability of a response to a diagnostic item regardless of other characteristics of the child, such as its gender.

Chapter 7 examines whether the genetic variants, in this case genotyped single nucleotide polymorphisms (SNPs), that are associated with educational attainment in adults, are also associated with school performance and educational achievement in children. The first study of SNPs associated with educational attainment in adults was reported in 2013 in a publication in *Science* (Rietveld et al., 2013). The effect sizes from this study were used to calculate polygenic scores and to compute the explained variance in school performance and educational achievement in sample of 12-year-olds. Next, it was tested whether the polygenic scores for educational achievement also have an effect on ADHD, as rated by mothers and teachers, thereby testing if the relation between ADHD and educational achievement can (partly) be explained through genetic pathways.

Chapter 8 tests whether the negative association between ODD and ADHD behavior and educational achievement can be explained by a causal effect or genetic pleiotropy only. These tests were done by analyzing data from monozygotic and dizygotic twins whose ODD and ADHD behavior was assessed by their mothers, at the ages 7 and 12 years. Data for educational achievement came from the standardized educational achievement test administered in the last grade of primary school (age 12).

This thesis is concluded with a summary of the main results and a general discussion (**Chapter 9**) and a Dutch summary (**Chapter 10**). The data collection procedures, study sample and measurement instruments used in this thesis are described in a series of **Appendices**.