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Genetic transmission of reading ability

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ABSTRACT

Reading is the processing of written language. Family resemblance for reading (dis)ability might be due to transmission of a genetic liability or due to family environment, including cultural transmission from parents to offspring. Familial-risk studies exploring neurobehavioral precursors for dyslexia and twin studies can only speak to some of these issues, but a combined twin-family study can resolve the nature of the transmitted risk. Word-reading fluency scores of 1100 participants from 431 families (with twins, siblings and their parents) were analyzed to estimate genetic and environmental sources of variance, and to test the presence of assortative mating and cultural transmission. Results show that variation in reading ability is mainly caused by additive and non-additive genetic factors (64%). The substantial assortative mating ($r_{father-mother}$ = 0.38) has scientific and clinical implications. We conclude that parents and offspring tend to resemble each other for genetic reasons, and not due to cultural transmission.

1. Introduction

Dyslexia, usually conceptualized as the lower tail of the word reading-ability distribution, tends to run in families. Children of dyslexic parents, as well as siblings of dyslexic children, have a higher change of developing dyslexia themselves (Snowling, Gallagher, & Frith, 2003; Torppa, Lyytinen, Erskine, Eklund, & Lyytinen, 2010; van Bergen, van der Leij, & de Jong, 2014; Vogler, Defries, & Decker, 1985). Their heightened risk is utilized in studies seeking neuro-anatomical, neuro-functional, cognitive, and environmental precursors of dyslexia. For instance, it has been found that children with familial risk have altered structural brain networks in language areas (Hosseini et al., 2013) and impaired auditory processing (Lyytinen et al., 2005; van der Leij et al., 2013). Despite the ubiquitous use of this familial-risk design in reading and language research, what remains to be resolved is the nature of the transmitted risk (van Bergen, de Jong, Maassen, & van der Leij, 2014). A mainly genetic cause for reading ability and disability implies that parents with reading problems pass on less advantageous genes, whereas a mainly environmental explanation would mean that these parents create a less advantageous home-literacy environment. Which of these two is the main driver has consequences for the interpretation of dyslexia precursors seen in at-risk children.

Evidence for the genetic explanation comes from twin and family studies, which indicate that genetic factors explain a large part of individual differences in children's word-level reading ability (henceforth called 'reading ability'). Reading ability (or decoding) is typically assessed by asking participants to read a list of words, and measuring accuracy or a combination of accuracy and speed (called fluency). The heritability of dyslexia and reading ability is high (60–70%) from a young age onwards (Hawke, Wadsworth, & Defries, 2006; Kovas et al., 2013). The heritability might be higher for timed compared to untimed tasks (Petrill et al., 2012). The current study was conducted in a large Dutch twin-family sample. The Dutch orthography (writing system) is less complex compared to English (Seymour et al., 2003). Hence, accuracy is close to ceiling and reading ability in Dutch is typically measured using fluency

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tasks (Patel, Snowling, & de Jong, 2004). This might be related to the even higher heritability found for reading ability in Dutch children (around 80%, van Leeuwen, van den Berg, Peper, Pol, & Boomsma, 2009). However, Samuelsson et al. (2008) did not find differences in heritability between orthographies. Alternatively, the high heritability found in the Netherlands may be due to the egalitarian educational system, which reduces environmental variance. Besides children, our study also includes adults. In adults, the heritability of reading has hardly been studied. One study in adult men found somewhat lower though still robust heritability estimates (45%, Kremen et al., 2005).

Evidence for environmental influences comes from twin studies, which sometimes find a significant influence of the environment that is shared between twins (Olson, Keenan, Byrne, & Samuelsson, 2014; Taylor, Roehrig, Hensler, Connor, & Schatschneider, 2010). This could be due to environmental transmission from parent to child, or due to other, indirect, effects having to do with sharing a household. Several studies indicate which shared household factors correlate with reading ability. Aspects identified thus far include the number of books in a household, how much parents read, and socio-economic status (Evans, Kelley, Sikora, & Treiman, 2010; Leseman & de Jong, 1998; Manolitsis, Georgiou, & Parrila, 2011). However, correlates that are observed in the home environment do not necessarily represent an environmental cause, since such factors may be influenced by the genotype of the parents who provide the home environment (Kendler & Baker, 2007). As parents both transmit their genes and provide the child with the home environment, this may induce a gene-environment correlation, that is, the home environment that the child experiences is related to his or her genotype. If a parental characteristic (e.g., reading ability) still influences an offspring's characteristic after controlling for common genes that influence both generations, then this influence acts through the environment, referred to as cultural transmission.

Thus far, only a few studies explored the association between children's and parents' reading ability. A Dutch and a Finnish familial risk study showed a moderate correlation between parents' and children's reading fluency (Torppa, Eklund, van Bergen, & Lyytinen, 2011; van Bergen, de Jong, Plakas, Maassen, & van der Leij, 2012). A recent Dutch family study (based on an unselected sample) reported a parent-offspring correlation for reading fluency of .35 (van Bergen, Bishop, van Zuijen, & de Jong, 2015). Two English studies tried to disentangle genetic and environmental influences within the family. A study that includes parent and (adoptive) child data (Kirkpatrick, Legrand, Iacono, & Mcgue, 2011) provides a genetically sensitive design. This study employed a broad construct of literacy (Wide Range Achievement Test), but did not explicitly test the nature of familial transmission. However, the pattern of correlations did not point to cultural transmission. Another adoption study (Wadsworth, Corley, Hewitt, Plomin, & Defries, 2002) showed that reading accuracy of parents and their biological offspring correlated around 0.2, whereas the association among parents and adopted children was absent. As adoptive children can only resemble parents because of cultural transmission, this study suggests that cultural transmission of reading ability is lacking. We aim to further investigate this possibility in an extended twin design, that combines the strength of the classical twin study with the option to study cultural transmission, when twins and their parents have been phenotyped on the same measures. In our study, we used a fluency task in a different orthography, thereby extending empirical research on genetic and cultural transmission of reading in a different culture.

Returning to van Bergen et al. (2015) and Wadsworth et al. (2002), they report spouse correlations of 0.16 and 0.26 respectively, indicating non-random, or assortative, mating. We are unaware of other studies reporting assortative mating for reading ability, but its presence is important for several reasons: it may bias heritability estimates downwards if not taken into account in a classical twin design (i.e., data from mono- and dizygotic twins), while simultaneously suggesting a larger influence of shared environment (Cavalli-Sforza & Bodmer, 1971; Eaves, Fulker, & Heath, 1989). Assortative mating may also signify that offspring of dyslexic parents are particularly vulnerable, as they may inherit genetic and environmental risk factors from both parents.

Here, we aimed to explore the association between parents' and offspring's reading skills further: in a sample of Dutch twins, their siblings and their parents, we estimated resemblance of family members on a commonly used word-reading task. We test if offspring resemble their parents, if there is assortative mating between parents, if there is resemblance among offspring and if this resemblance is larger for monozygotic twin pairs than for dizygotic pairs and non-twin siblings. This is the first general-population study that explores the family resemblance of reading ability in a genetically-sensitive design.

2. Methods

2.1. Participants

Participants were recruited from the Netherlands Twin Register (NTR, Boomsma et al., 2006; van Beijsterveldt et al., 2013; Willemsen et al., 2013). Reading scores were collected in two samples. The first sample, which we will refer to as the twin-sibling sample (n = 310 NTR participants), consists of twin pairs with their older sibling from a longitudinal study on the development of brain and cognition (BrainSCALE, van Soelen et al., 2012). Measurements took place around the twins' 9th, 12th and 17th birthday. If available, reading data of the first measurement were used (n = 294), otherwise from the third measurement (n = 16). This sample consisted of 47 monozygotic (22 male, 25 female) and 70 dizygotic twin pairs (21 male, 21 female, 18 opposite sex). Data for 41 brothers and 53 sisters aged between 9 and 21 years (mean = 12.62, sd = 2.61) were simultaneously collected.

The second sample is a parent-offspring sample, consisting of 894 NTR participants from a population-based study on cognition and psychophysiology (Swagerman et al., 2015). For this study, we included 436 twins (34 male and 72 female MZ twin pairs, 19 male and 40 female DZ twin pairs, and 50 opposite sex pairs), 33 brothers (mean age 35.9, sd = 16.1), 38 sisters (mean age 35.7, sd = 18.8), 125 fathers (mean age 64.0, sd = 10.2), and 158 mothers (mean age 61.3, sd = 10.8).

In total, data were available for 1100 participants from 431 families, of which 386 had at least two family members. On average, the mean age of this sample was 43.8 (sd = 20.4). These participants are representative of the general population: on average, adults had engaged in 14 years of education (range 6–20 years).

2.2. Materials

2.2.1. Reading test

Participants were given a list of Dutch words and were asked to correctly read out loud as many words as possible within one minute. Each participant was assessed on one of two highly similar tests, which we will refer to as one-minute-test 1 (OMT1) and one-minute-test 2 (OMT2).

OMT1. The OMT1 consists of 120 multisyllabic words, increasing in difficulty from two to four syllables (list 3C, Verhoeven, 1995). The manual reports a reliability of 0.86–0.92 in 9–12-year-olds (Moelands, Kamphuis, & Verhoeven, 2008).