Heritability of Intelligence

Nele Jacobs,1,2 Jim van Os,1,3 Catherine Derom,4,5 and Evert Thiery4

1 Department of Psychology, Open University of the Netherlands, Heerlen, the Netherlands
2 Department of Psychiatry and Neuropsychology, South Limburg Mental Health Research and Teaching Network, EURON, Maastricht University, the Netherlands
3 Division of Psychological Medicine, Institute of Psychiatry, London, United Kingdom
4 Association for Scientific Research in Multiple Births, Ghent, Belgium
5 Department of Human Genetics, University Hospital Gasthuisberg, Katholieke Universiteit Leuven, Leuven, Belgium

This article discusses findings of two recent studies conducted in collaboration with the East Flanders Prospective Twin Survey in the field of cognitive ability. The first study examined the effect of chorion type on heritability estimates of intelligence in children. The second study investigated the causes of association between child psychopathology and lower cognitive ability. Findings of these studies are discussed in the light of the current view on cognitive ability (or ‘g’) and recommendations for future research are made.

Effect of Chorion Type on Heritability Estimates

Intelligence is one of the oldest topics in behavior genetics research and it is probably the most complex — and most controversial — of all complex traits. In spite of different theoretical views of intelligence (e.g., Cattells crystallized and fluid intelligence, Cattell, 1971; Sternberg’s triarchic theory of intelligence, Sternberg, 1999; and Gardner’s multiple intelligences, Gardner, 2000), the notion of ‘general cognitive ability’ as a basic general factor of mental ability, represented by the symbol ‘g’ (Spearman, 1927), is well accepted. In psychometric terms, ‘g’ is operationalized by the covariance among diverse tests of cognitive abilities such as abstract reasoning, spatial, verbal and memory abilities (Plomin, 2003) and most psychometric researchers agree that the ‘g’ factor is sensitive to individual differences in abilities to learn, reason and solve problems (Toga & Thompson, 2005). Since long, behavior genetic researchers are trying to explain these observed individual differences in ‘g’ in terms of nature (genetics) versus nurture (environment). The first twin study and adoption studies on ‘g’ were conducted in the 1920s and suggested substantial genetic influences. Since then, with the exception of personality assessed by self-report questionnaires, more research has addressed the genetics of ‘g’ than that of any other human characteristic. Heritability estimates vary from 40% to 80%, but meta-analyses yield estimates of about 50% and even higher in studies of adults (Craig & Plomin, 2006). However, none of these studies looked at the possible confounding effect of chorion type on the heritability estimates. After all, according to differences in the antenatal development, three types of monozygotic (MZ) twins can be distinguished: approximately 32% are dichorionic (DC, each fetus having its own chorion and amnion), nearly 66% are monochorionic–diamnionic (MC–DA, twins sharing a common chorion, but having their own amnion) and 2 to 3% of the MZ twins are monochorionic–monoaamnionic (MC–MA, twins sharing one chorion and one amnion). As some studies suggested that chorion type may influence postnatal phenotypes such as intelligence (Spitz et al., 1996), this was investigated in a sample of 451 twins pairs aged 8 to 14 from the East Flanders Prospective Twin Survey (EFPTS) as this twin survey is unique in having reliable information about the chorionicity of the twins. Results of this study as reported by Jacobs at al. (2001) showed a small but significant effect of chorion type on the WISC-R subscales Arithmetic and Vocabulary: as expected, MC twins, who share the same placenta and have a common blood circulation, resembled each other more that DC–MZ twins (see also Table 1). In addition, high heritability estimates were found for almost all subscales as well as for total IQ scores such as verbal IQ (82%), performance IQ (73%) and total IQ (83%), which confirmed previous studies (Boomsma, 1993; Wright et al., 2001).

Genetic Association With Child Psychopathology

The topic of ‘g’ is without doubt an important one. After all, ‘g’ predicts important social outcomes such as scholastic achievement, employment, lifetime income and even health-related parameters such as life expectancy (Toga & Thompson, 2005). In addition, ‘g’ is specifically relevant to molecular psychiatry because mild mental retardation appears to be the low extreme of the normal distribution of ‘g’. Moreover, at least 200 single-gene disorders include mental retardation (Spitz et al., 1996), this was investigated in a sample of 451 twins pairs aged 8 to 14 from the East Flanders Prospective Twin Survey (EFPTS) as this twin survey is unique in having reliable information about the chorionicity of the twins. Results of this study as reported by Jacobs at al. (2001) showed a small but significant effect of chorion type on the WISC-R subscales Arithmetic and Vocabulary: as expected, MC twins, who share the same placenta and have a common blood circulation, resembled each other more that DC–MZ twins (see also Table 1). In addition, high heritability estimates were found for almost all subscales as well as for total IQ scores such as verbal IQ (82%), performance IQ (73%) and total IQ (83%), which confirmed previous studies (Boomsma, 1993; Wright et al., 2001).
In a study (Jacobs et al., 2002) conducted in a sample of 376 twin pairs aged 8 to 14 from the EFPTS, it was found that genetic factors accounted for 84% of this modest but significant phenotypic correlation ($r = –.19$; see Figure 1). It was concluded that in children three different genetic factors may exist: one that solely affects the liability to child psychopathology, one that had only an effect on 'g' and one that influences both phenotypes. This finding of a shared genetic factor influencing (the low end of) 'g' and child psychopathology, can help the search for specific genes in comorbid samples by increasing the power to detect a quantitative trait locus (QTL; Boomsma & Dolan, 1998), as illustrated by a recent study by DeYoung and colleagues in which an allelic variation in the dopamine D4 receptor gene was suggested as a genetic factor moderating the association between externalizing behavior and cognitive ability (DeYoung et al., 2006).

**Discussion**

General cognitive ability is one of the most inherited dimensions of human behavior, even after taking the possible confounding effect of chorionicity into account. It should be noted that a (partly) genetically determined 'g' does not necessarily imply that there is a single fundamental brain process that permeates all other brain processing, such as 'a speedy brain', neural plasticity or the quality and quantity of neurons. It has been proposed that 'g' exits in the brain in the sense that diverse brain processes are genetically correlated (Plomin, 2003). Our finding of a shared genetic factor influencing two correlated phenotypes may be a good illustration of this view. Genetic factors involved in 'g' were also found to be associated with child psychopathology.

Table 1

<table>
<thead>
<tr>
<th>WISC—R subscale</th>
<th>Best-fitting model</th>
<th>a</th>
<th>95% CI</th>
<th>c</th>
<th>95% CI</th>
<th>ch</th>
<th>95% C.I.</th>
<th>e</th>
<th>95% C.I.</th>
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<td>.51</td>
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<td>.17</td>
<td>.14—.21</td>
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Note: Table adapted from Jacobs et al. (2001).

A indicates additive genetic factors; C, common environmental factors; E, individual–specific environmental factors.
future molecular genetic research needs to incorporate environmental variables and to examine gene–gene interactions in powerful designs with large samples.

To conclude, ‘g’ is one of the most fascinating topics in psychology and for some time have been prompted to unravel the mystery of this complex trait. As described above, studies in collaboration with the EFPTS have made a significant contribution to this ongoing exploration of ‘g’, taking advantage of the unique features of this twin registry. Therefore, one may look forward to future EFPTS studies including environmental and genetic variables.

**Acknowledgments**

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**References**


Figure 1

The genetic and environmental parameters estimates from the best fitting model, adapted from Jacobs et al. (2002).

Note: The variance in liability to each trait is divided into that due to additive genetic factors (A and A), common environmental effects (C and C) and individual-specific environmental factors (E and E). Whereby CBCL indicates Child Behavior Checklist and WISC-R, Wechsler Intelligence Scale for Children — Revised. Paths, which are the standardized regression coefficients, must be squared to equal the proportion of variance accounted for. The phenotypic correlation between Child psychopathology and Cognitive ability is decomposed into that due to the correlation of additive genes (r = –.27), the correlation of individual-specific environmental factors (r = –.17).


