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Intelligence and birth order in boys and girls

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Abstract

The relation between intelligence and birth order was shown in a recent publication [Bjerkedal, T., Kristensen, P., Skjeret, G. A. & Brevik, J. I. (2007). Intelligence test scores and birth order among young Norwegian men (conscripts) analyzed within and between families. Intelligence, 35, 503–514] to be negative. Subjects in this and in an influential earlier study [Belmont, L. & Marolla F. A. (1973). Birth order, family size, and intelligence. Science, 182, 1096–1101] were all men. We tested if the association of IQ and birth order is the same in men and women. Longitudinal IQ data were available from 626 Dutch twin pairs at ages 5, 12 and 18 years. The number of older siblings in these twin families was between zero and five, and was recoded into 3 categories (0, 1 and 2, or more). IQ data were analyzed with a model in which age cohort, number of older sibs, sex and all interactions were included as fixed effects. The dependency between twins was modeled as a function of additive genetic effects (A) and common environment (C) shared by children from the same family. Effects of A, C and unique environment (E) were allowed to differ as a function of age. The correlation across time between IQ scores was modeled a function of genetic and environmental factors.

The test for the effect of *N* of older sibs was significant [$F_{(2,827)}=6.51$ ($p=0.0016$)], while the interaction of *N* of older sibs with sex was not significant [$F_{(2,933)}=1.93$, $p=0.15$]. Heritability for IQ was estimated at 37% at age 5 (C explained 34% of the variance). At ages 12 and 18 heritability for IQ was 81% and 82%, respectively. At these ages C did not contribute to IQ variation. We conclude that the dependency of IQ scores on birth order does not differ for boys and girls. We discuss these results in the context of the general findings of the absence of common environmental influences on IQ scores in the genetic analyses of adolescent and adult twin data.

Keywords: Birth order; Twins; IQ

1. Introduction

In 1973 an influential study in Dutch men showed the relation of IQ and birth order to be negative (Belmont & Marolla, 1973). This result was recently replicated in a large Norwegian study of male conscripts, which tested the relation between intelligence and birth order both within and between families (Bjerkedal, Kristensen,

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Skjeret & Brevik, 2007). By demonstrating that the negative association was also found within families, explanations that involve a relation between low parental intelligence and larger family size could be rejected. In a second paper Kristensen and Bjerkedal (2007) provided evidence that the negative association is explained by the dependency of IQ scores on social rank within the family. This explanation makes other, biological, interpretations unlikely, such as the hypothesis of an effect of maternal antibody attack on the fetal brain (maternal antibody levels tend to increase by higher birth orders). In their large sample, Kristensen and Bjerkedal (2007) could look at intelligence scores of boys who had different social and biological ranks within the family, for example, boys who grew up in families with deceased older siblings. Their results showed higher IQ scores for second-borns who had lost an older sibling than for second-born subjects ranked second both socially and biologically.

The large datasets available in the Dutch and Norwegian studies came from army conscripts. Thus, subjects in both these studies were all male. We tested if the negative association of IQ and birth order might be different for boys and for girls. Using data on IQ and birth order collected in subjects registered with the Netherlands Twin Register (Bartels et al., 2007; Boomsma et al., 2006) we explored whether the association of IQ and birth order is the same in men and women. IQ data were available from 626 twin pairs at ages 5, 12 and 18 years who had participated in studies of cognitive development. One group of twins participated at ages 5, 12 and 18 years, a second group at ages 5 and 12 years and there was one group that only had IQ data at age 18.

2. Methods

2.1. Subjects

IQ data were available in twins who had taken part in studies on cognition at ages 5, 12 and 18 years. At age 5 twins (N=811) were tested as part of studies on development of brain function (Boomsma & van Baal, 1998) and on neuropsychological development (Polderman et al., 2006). At age 12 the same twins (N=666) took part in developmental studies of cognition (Bartels, Rietveld, Baal van, & Boomsma, 2002; Polderman, Stins, Posthuma, Gosso, Verhulst, & Boomsma, 2006). At age 18 the twins (N=638) took part in studies of physical and mental development (Hoekstra, Bartels, & Boomsma, 2007) and of brain development and cognition (Rijsdijk, Vernon, & Boomsma, 2002). Twins in the first project had also taken part in the IQ studies at ages 5 and 12 years. The number of older siblings was between zero and five, and was recoded into 3 categories (0, 1 and >1). Table 1 offers the breakdown of the number of twins at each age as a function of sex and N of older sibs. The last column of Table 1 gives the number of monozygotic (MZ) and dizygotic (DZ) twins at each age.

Table 1
Number of twin individuals (boys and girls) in each age group (cross-sectionally) as a function of the number of older siblings; total number of participants as a function of zygosity (last column)

	0 older sibs	1 older sib	>1 older sib	Total
	Male/female	Male/female	Male/female	MZ/DZ
Age 5	174/194	146/149	62/86	396/415
Age 12	141/153	126/122	47/77	329/337
Age 18	116/151	124/123	49/75	276/362

For same-sex twins zygosity was based on typing of DNA or blood group polymorphisms. The number of unique observations (i.e. number of twin pairs, regardless of the number of times they took part) was 131 MZmale, 101 DZmale, 164 MZfemale, 113 DZfemale and 117 DZ opposite sex twin pairs from 626 families.

2.2. IQ measures

At age 5 children completed the Revised Amsterdamse Kinder Intelligentie Test (RAKIT, (Bleichrodt, Drenth, Zaal, & Resing, 1984). The RAKIT is a Dutch psychometric intelligence test for children aged 4 to 11 years. The short version of the RAKIT was used, which has six subtests with age-appropriate items, measuring verbal and nonverbal abilities. IQ scores were based on the sum of the subtests scores, which were transformed into standardized scores. The standardization was based on a population sample of Dutch children; the norms for standardization were the same for boys and girls.

At age 12 the Dutch version of the Wechsler Intelligence Scale for Children — Revised (WISC-R) (Van Haasen et al., 1986) was used. The complete test, consisting of 6 verbal and 6 nonverbal subtests, was administered in the first study, in the second study a short version, consisting of 6 subtests was used. Standardized IQ scores were based on results of same-aged children in the Netherlands. The transformation from raw scores into standardized IQ scores was based on the same norms for boys and girls.

At age 18 the Dutch version of the Wechsler Adult Intelligence Scale (WAIS-III) (Wechsler, 1981, 1997) was administered. The twins completed 6 verbal and 5 nonverbal tests. The subtests were standardized based on a population sample of same-aged subjects in the Netherlands. Standardization norms were the same across the sexes.

2.3. Statistical analyses

Within each age by sex group IQ scores were standardized (mean = 0, SD = 1). The data were analyzed with a mixed model analysis (Beem & Boomsma, 2006) using the mixed procedure in SAS (SAS Institute Inc., 2004). The full model included age cohort (age at testing: 5, 12 or 18 years), number of older sibs (0, 1 or >1), sex (male or female) and all interactions as fixed effects. Denoting these fixed effects by α_a, β_b and γ_k (where the subscripts refer to the levels of the factor), the general constant by μ, the first order interactions by terms such as $\alpha\beta_{ij}$ and second-order interaction by $\alpha\beta\gamma_{ijk}$, the fixed part of the model becomes $\mu+\alpha_a,+\beta_b+\gamma_k+\alpha\beta_{ab}+\alpha\gamma_{ak}+\beta\gamma_{bk}+\alpha\beta\gamma_{abk}$. The genetic, random part of the model for twin j in family i is $A_{ij}+C_i+E_{ij}$, where A_{ij} is the additive genetic effect, C_i is the common environment effect, and E_{ij} is the unique environment effect. MZ twins share both A and C; DZ twins share 50% of their genes and also share all effects due to C (Boomsma, Busjahn, Peltonen, 2002). Parameter estimation was by maximum likelihood.

Two models were first fitted for each age cohort separately. Both models included the number of older sibs, sex and their interaction as fixed effects. The models were fitted once with and once without the C effect. According to the AIC criterion, the C effect needed to be included only for the 5 years age cohort. We used the regular AIC throughout for model selection, as corrections of the AIC to account for the one-sidedness of hypotheses on variance components do not at present appear to uniformly improve model selection (Hughes & King, 2003).

In the longitudinal analyses the most general model included fixed effects and their interactions and all random effects and their unrestricted covariances, except that covariances of the genetic effects satisfied the usual restriction that the MZ covariance is twice the DZ covariance. We first simplified the covariance structure of the random C effects. The common environment effects for age groups 18 and 12 were successively removed, the order of removal being determined by the p-values for the associated variance components in the full model. The AIC criterion improved for both reduced models. Next the fixed part of the model was reduced with the order of the interaction and p-values of the Satterthwaite approximation of the F-statistic guiding the order of deletion of effects. The second-order interaction and the cohort by sex, cohort by N of older sibs, and the sex by number of older sibs interactions were successively deleted. Removal of these effects improved the AIC criterion. Finally the AIC was improved by removal of the cohort and sex main effects. The effect of number of older sibs was not removed, as its F-value was significant using a Satterthwaite approximation.

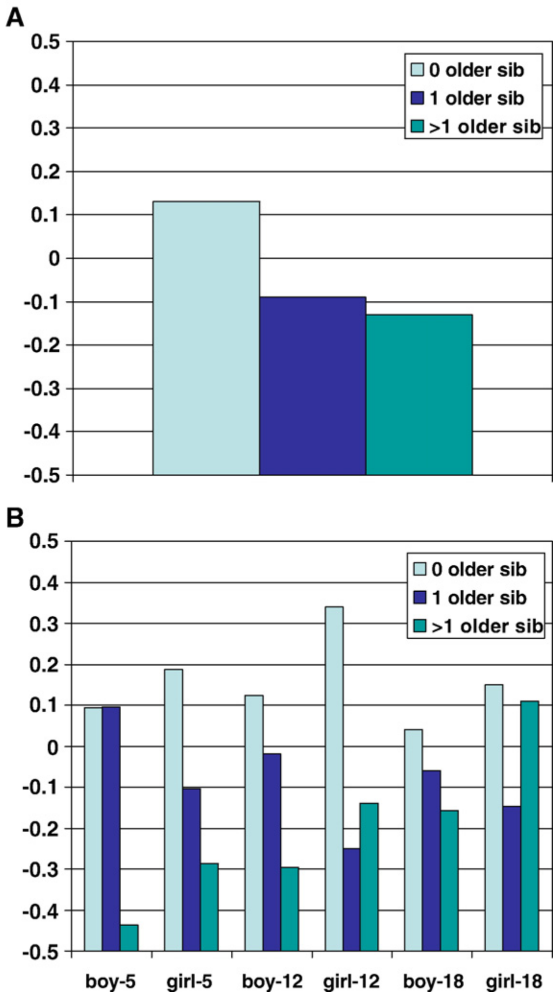

Fig. 1. A. Marginal means for standardized IQ scores for children with 0, 1 or 2 older siblings, summarized over 3 age groups. B. Means for standardized IQ scores for children with 0, 1 or 2 older siblings, separately for 5, 12 and 18 year old boys and girls.

3. Results

The reduced model without common environment for the age groups 12 and 18 and only N of older sibs as a fixed effect described the data well (−2 Log-

Likelihood for the full and reduced model was 4933.2, $df=36$, and 4958.3, $df=16$, $\chi^2=25.1$, respectively, $\Delta df=20$).

The test for the number of older siblings was significant [$F_{(2,827)}=6.51$ ($p=0.0016$)]. The estimated means (see Fig. 1A) showed the highest IQ scores in children without any older siblings (mean = 0.13; SE = 0.05), followed by children with one older sibling (mean = −0.09; SE = 0.05). Children with 2 or more older sibs obtained the lowest scores (mean = −0.13; SE = 0.07). Post-hoc tests showed the difference between the group without older sibs and the other 2 groups to be significant ($p<0.01$ Tukey adjusted). Fig. 1B shows the effect of N of older sibs at each age and separately for boys and girls. At each age, the subjects without older sibs obtain the highest IQ scores. At each age also, the effect is similar for boys and for girls and the interaction between N of older sibs and sex is not significant [$F_{(2,933)}=1.93$, $p=0.15$]. Heritability of IQ was estimated at 37% at age 5, at 81% at age 12 and 82% at age 18. At age 5 years, common environment explained 34% of the variance.

4. Discussion

We replicate the negative association between IQ and birth order. The effect is seen in both boys and girls, and there is no significant interaction between the number of older siblings and sex. In an earlier study Record, McKeown and Edwards (1969) reported a somewhat stronger effect for boys than for girls in a within-family comparison of verbal abilities. In this study, 11-year old boys suffered more than girls from being later born (see their Table 2).

We did not observe an interaction of age cohort with the birth-order main effect or with the birth order × sex interaction, indicating that the effect of birth order on IQ scores at ages 5 and 12 years is as important as at age 18 years. Sulloway (2007) notices, in a commentary on the findings of Kristensen and Bjerkedal (2007), that the effect of birth order on IQ is reversed in some studies (i.e. second-borns score higher on IQ than first-borns). Sulloway explains these seemingly contradictory findings as dependent on the age at which IQ was assessed (see also Zajonc & Sulloway, 2007) with the first-born starting to surpass the younger sibling around the age of 8 years. We fail to observe such an effect in our dataset, in which at age 5 years first-born twins have higher IQs than children who have older siblings. However, there is a suggestion in the data (see Fig. 1B) that for boys the effect is apparent only for boys with at least 2 or more older siblings.

The analysis of the covariance structure indicated an effect of common environment ("C") at age 5 years, explaining a sizeable proportion of the variance in IQ scores. However, at ages 12 and 18 years, the familial variation in IQ was sufficiently accounted for by genetic factors and no significant effect of common family environment was detected. This finding is in line with other twin and adoption studies of IQ (for reviews see e.g. Bouchard, & McGue, 2003; Posthuma, de Geus, & Boomsma, 2002). Please note that the genetic covariance analyses were carried out simultaneously with the analysis of the fixed effect of N of older sibs on the mean IQ scores. Thus, at age 5, there is a large proportion of common environmental variance not due to birth order. We repeated the genetic analyses after removing the effect of N of older sibs from the model. This resulted in increases of C from 1 to 3% for the three age groups. Clearly, twins share the same birth order within the family. This is in contrast to singleton children growing up in the same household for whom birth order by definition is a nonshared environmental influence. A small "twin" effect could thus be attributable to birth order. However, in the covariance-structure modeling of the resemblance between twins this shared effect is too small to show up as a main effect. The absence of an effect of common environment on IQ variation in adolescence (and adulthood) while at the same time finding evidence for a birth-order effect thus shows the lack of power of the classical twin study to detect the effect of common environment, unless it is fairly large.

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References

Bartels, M., Rietveld, M. J. H., Baal, G. C. M. van, & Boomsma, D. I. (2002). Heritability of educational achievement in 12-year olds and the overlap with cognitive ability. *Twin Research*, *5*, 544−553.

Bartels, M., Hudziak, J. J., Derks, E. M., van Beijsterveldt, C. E. M., Stroet, T. M., Polderman, T. J. C., et al. (2007). Young — Netherlands Twin Register (Y-NTR): A longitudinal multiple informant study of problem behavior. *Twin Research of Human Genetics*, *10*, 3−11.

Beem, A. L., & Boomsma, D. I. (2006). Implementation of a combined association-linkage model for quantitative traits in linear mixed model procedures of statistical packages. *Twin Research of Human Genetics*, *9*, 325−333.

Belmont, L., & Marolla, F. A. (1973). Birth order, family size, and intelligence. *Science*, *182*, 1096−1101.

Bjerkedal, T., Kristensen, P., Skjeret, G. A., & Brevik, J. I. (2007). Intelligence test scores and birth order among young Norwegian men (conscripts) analyzed within and between families. *Intelligence*, *35*, 503−514.

Bleichrodt, N., Drenth, P. J. D., Zaal, J. N., & Resing, W. C. M. (1984). *Revisie Amsterdamse Kinder Intelligentie Test [Revised Amsterdam Child Intelligence Test].* Lisse, the Netherlands: Swets & Zeitlinger B.V.

Boomsma, D. I., & Baal, G. C. M. van (1998). Genetic influences on childhood IQ in 5- and 7-year old Dutch twins. *Develop Neuropsychology*, *14*, 115−126.

Boomsma, D. I., de Geus, E. J., Vink, J. M., Stubbe, J. H., Distel, M. A., Hottenga, J. J., et al. (2006). Netherlands Twin Register: From twins to twin families. *Twin Research of Human Genetics*, *9*, 849−857.

Boomsma, D., Busjahn, A., & Peltonen, L. (2002). Classical twin studies and beyond. *Nature Reviews Genetics*, *3*(11), 872−882.

Bouchard, T. J., Jr., & McGue, M. (2003). Genetic and environmental influences on human psychological differences. *Journal of Neurobiology*, *54*, 4−45.

Hoekstra, R. A., Bartels, M., & Boomsma, D. I. (2007). Longitudinal genetic study of verbal and nonverbal IQ from early childhood to young adulthood. *Learning Individual Differences*, *17*, 97−114.

Hughes, A. W., & King, M. L. (2003). Model selection using AIC in the presence of one-sided information. *Journal of Statistical Planning and Inference*, *115*, 397−411.

Kristensen, P., & Bjerkedal, T. (2007). Explaining the relation between birth order and intelligence. *Science*, *316*, 1717.

Rijsdijk, F. V., Vernon, P. A., & Boomsma, D. I. (2002). Application of hierarchical genetic models to Raven and WAIS subtests: A Dutch twin study. *Behavior Genetics*, *32*, 199−210.

Polderman, T. J. C., Gosso, M. F., Posthuma, D., Van Beijsterveldt, T. C., Heutink, P., Verhulst, F. C., et al. (2006). A longitudinal twin study on IQ, executive functioning, and attention problems during childhood and early adolescence. *Acta Neurologica Belgica*, *106*, 191−207.

Polderman, T. J. C., Stins, J. F., Posthuma, D., Gosso, M. F., Verhulst, F. C., & Boomsma, D. I. (2006). The phenotypic and genotypic relation between working memory speed and capacity. *Intelligence*, *34*, 549−560.

Posthuma, D., Geus, E. J. C. de, & Boomsma, D. I. (2002). Genetic contributions to anatomical, behavioral and neurophysiological indices of cognition. In R. Plomin, J. C. DeFries, I. W. Craig, & P. McGuffin (Eds.), *Behavioral Genetics in the Postgenomic Era* (pp. 141−161). Washington DC: APA Books.

Record, R. G., McKeown, T., & Edwards, J. H. (1969). The relation of measured intelligence to birth order and maternal age. *Annals of Human Genetics*, *33*, 61−69.

SAS Institute Inc. (2004). *SAS/STAT® 9.1 User's Guide.* Cary, NC: SAS Institute Inc.

Sulloway, F. J. (2007). Birth order and intelligence. *Science*, *316* (5832), 1711−1712.

Van Haasen, P. P., De Bruyn, E. E. J., Pijl, Y. J., Poortinga, Y. H., Lutje-Spelberg, H. C., et al. (1986). *Wechsler Intelligence Scale for Children—Revised, Dutch Version.* Lisse: Swets and Zetlinger B.V.

Wechsler, D. (1981). *The Wechsler Adult Intelligence Scale—Revised.* New York: Psychological Corporation.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale—Third Edition, Dutch Version.* Lisse, the Netherlands: Swets & Zeitlinger B.V.

Zajonc, R. B., & Sulloway, F. J. (2007). The confluence model: birth order as a within-family or between-family dynamic? *Personality & Social Psychology Bulletin*, *33*(9), 1187−1194.