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The Flynn effect in sibships: Investigating the role of age differences between siblings

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ABSTRACT

The aim of the study was to investigate the relationship between the Flynn effect and the effects of age differences between siblings on the intelligence difference between them. In Norway, the secular trends in intelligence-test score means vary both in magnitude and direction. We identified three periods: one period where the mean intelligence increased across birth cohorts (1950–1956), one period where the means decreased (1976–1983), and one period with no appreciable Flynn effect (1960–1965). In a data base comprising birth year and intelligence data on more than 900,000 males meeting at mandatory conscription between their 18th and 21st birthday, we identified more than 69,000 brother pairs where both brothers had been born in exactly one of the periods mentioned above. In this study group the relationship between age differences between brothers and the intelligence difference could be studied. The results showed that in the period with increasing intelligence means across cohorts, the intelligence difference between brothers decreased with increasing age differences. In the period with decreasing means, the difference between the later-born and the earlier-born brother increased across age differences. No systematic effects of age difference on mean intelligence differences were found in the period without a Flynn effect. Regression analyses showed that the Flynn effect can be quite well predicted from the effects of the age differences between brothers on their intelligence-test scores. We conclude that the factors causing the Flynn effect also work within sibships. Hypotheses positing that the Flynn effect is solely caused by between-families factors (e.g. the heterosis hypothesis) are weakened. The present results also entail that the birth order effect observed in Norway is in part conditional on the Flynn effect.

1. Introduction

Secular increases of mean intelligence-test scores — coined the Flynn effect by Herrnstein and Murray (1994) — have been intensely studied since the seminal papers by Flynn (1984, 1987). Secular increases of intelligence-test score means have been found in a number of countries in Europe, North America and Asia (Flynn, 1984, 1987, 1998a). More recently, a Flynn effect has been found in Africa (Daley, Whaley, Sigman, Espinosa, & Neumann, 2003). In some Northern European countries, like Norway and Denmark, the Flynn effect has shown decreasing gains, and have stopped or even reversed (Sundet, Barlaug, & Torjussen, 2004; Teasdale & Owen, 2005). Rodgers (1999) pointed out that the secular changes of intelligence means may be unevenly distributed across ability levels. In Denmark and Norway it was found that the intelligence gains were to a large extent caused by decreasing prevalence of low scorers, resulting in decreasing variances (Sundet et al., 2004; Teasdale & Owen, 1989, 2000). In other countries, the gains seem to be

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more evenly distributed across levels of ability (Flynn, 1998a). Recently, it has been shown that the mean intelligence in sibships of different sizes increases across cohorts, and that these increases are close to parallel over wide ranges of cohorts (Sundet, Borren, & Tambs, 2008). An independent but modest effect of the increase of the proportions of small families at the expense of the proportions of larger ones on the mean intelligence scores has also been demonstrated, especially in the cohorts born in the late 1930's compared to the cohorts born later (Sundet, Borren, & Tambs, 2008).

The cause(s) of the Flynn effect are still very much under debate. Rodgers (1999) distinguished between factors working between families and factors working within families. A majority of the hypotheses concerning the Flynn effect have proposed environmental factors including improved education, better health care, improved nutrition and changing test-taking attitudes (cf. Neisser, 1998). Common to the environmental hypotheses is that they propose that there are some environmental change(s) across generations that influence all the individuals in a population in a more or less similar way. Thus, the Flynn effect should be visible both within and between families. For instance, in periods with distinct secular increases in intelligence scores, the age differences between siblings should influence the relationship between their scores such that the scores of the later-born siblings are expected to be relatively high compared to the scores of earlier-born siblings, and more so with larger age gaps.

With a few notable exceptions, the possible contributions of genetic factors to the Flynn effect have largely been disregarded. Dickens and Flynn (2001) introduced gene–environment correlations to account for the combination of a substantial heritability of intelligence and increasing means across generations (for a critique of the Dickens and Flynn model, see Rowe and Rodgers, 2002). Mingroni (2004, 2007) pointed to the possible contribution of changing mating patterns. While it is clear that the gene pool of a population cannot change appreciably within the small time intervals of a few generations, the *distribution* of the genes in the gene pool may change quite dramatically. In fact, this is just what is happening when a group of people change their mating habits from marrying biological relatives to marrying biologically unrelated persons. Mating with biologically related persons may lead to inbreeding depression of psychological traits. There is some evidence that inbreeding depression of intelligence may occur (Schull & Neel, 1965). When mating habits change along the lines indicated above, the inbreeding depression will decrease with decreasing rates of inbreeding, entailing a Flynn effect. It follows that the Flynn effect will come to an end when the rate of inbreeding approaches zero. The benevolent effects of decreasing inbreeding are, broadly speaking, due to increasing rates of hetereozygotes at the expense of homozygotes, and the phenomenon is commonly termed heterosis or hybrid vigor.

Michael Mingroni (2004, 2007) has argued that the Flynn effect is caused by heterosis. The heterosis hypothesis entails that the Flynn effect is a *between-families* effect (Rodgers, 1999). Consider a period with increasing secular trends in intelligence means. According to the heterosis hypothesis, the secular trends should not appear *within families* (i.e. within sibships). The relationship between the intelligence-test scores of earlier-born and later-born siblings should be unaffected by the secular increases of intelligence-test scores in the population at large. Accordingly, the mean intelligence difference between e.g. the first-born and second-born siblings should remain the same irrespective of the age difference between the siblings.

In sharp contrast, hypotheses that propose that increasing means across generations ("positive" Flynn effect) are caused by changing environments, predict that the intelligence of the later-born siblings should increase relative to the intelligence of the earlier-born, and more so the farther they are separated in age. In periods where the Flynn effect is absent, no such age-difference effects should appear (according to both the heterosis hypotheses and environmental hypotheses). Also, changing environments should be expected to cause *decreasing* intelligence-test scores in later-born siblings relative to earlier-born siblings in periods of decreasing secular trends in intelligence ("negative" Flynn effect).

While the relationship between age spacing and intelligence has been studied in some detail (Brackbill & Nichols, 1982; Grotevant, Scarr, & Weinberg, 1977; Nuttal & Nuttal, 1979; Zajonc, 1976), only a few studies have directly addressed the effect of age differences between siblings on the intelligence difference between them. Belmont, Stein and Zybert (1978) investigated the intelligence difference between brothers in 535 Dutch brother pairs in two-child sibships and did not detect any age-difference effects on intelligence differences. In a recent large-scale study of birth order effects in Norwegian conscripts (a subset of the material used in the present paper), it has been found that the age differences between brothers influence the intelligence differences between them (Bjerkedal, Kristensen, Skjeret, & Brevik, 2007). Clearly, more studies of the effects of age differences between siblings on intelligence-test scores are needed.

In Norway, there have been periods with a substantial positive Flynn effect, a comparatively weak Flynn effect, and periods with a distinct negative Flynn effect (Sundet et al., 2004). We also have access to within-sibship data, including age differences between siblings for all these periods. This data set gives an excellent opportunity to test one of the central predictions of the heterosis hypothesis. The main aim of the present study is to investigate the intelligence-test score differences between siblings as a function of the age spacing between them. The age-difference effects on intelligence-test score differences will then be compared to the secular changes of the intelligence score means in periods with varying direction and magnitude of the Flynn effect. We have also investigated how the birth order that seems to be present in Norway (Bjerkedal et al, 2007) is related to the Flynn effect.

2. Methods and materials

2.1. Measures

The intelligence-test scores analyzed in the present paper were obtained from the National Conscript Service. In Norway, military service is mandatory for all able young men. Before entering the service, they meet before a conscript board, where medical and psychological status, including intellectual ability, is assessed. Around 90% of the men liable for service attend, and most of them (around 95%) meet between their 18th and 21st birthday. Thus, almost all the conscripts have been tested at approximately the same age. Common reasons for non-attendance are serious illness, functional disorder, imprisonment, and working abroad or at sea.

Intelligence-test data comprised General Ability scores given in stanine units ($M=5$, $SD=2$). General Ability is a composite score calculated from the scores on three speeded tests (Arithmetic, Word similarities and Figures). The General Ability scores were obtained by transforming the raw scores on each separate test in a standardization sample into normally distributed *F*-scores ($M=50$, $SD=20$), and subsequently added and transformed into stanine scores. The Arithmetic test (30 items), presented in prose, purports to measure arithmetic and elementary algebraic ability but also logical reasoning ability and is quite similar to the Arithmetic test in the Wechsler Adult Intelligence Scale (WAIS). The Word Similarities test (similar to the Vocabulary test in WAIS, comprising 54 items) is a synonym test. The Figures test (36 items) was constructed to be similar to Raven Progressive Matrices. The contents of the tests remained unchanged over the time period covered by the present study. The format of the Arithmetic test was changed from open-ended answers to multiple choice in the early 1990's. The test–retest reliabilities of Arithmetic, Figures and Word Similarities as observed in a sample of 14 year old adolescents ($N\approx800$) in the mid 1950's were 0.84, 0.72 and 0.90, respectively (Sundet et al., 2004). In a smallish sample ($N=48$), the correlation between General Ability and the commonly used WAIS IQ (Cronbach, 1964) has been found to be in the mid 0.70's, with time spans between the two tests varying from 2 to 25 years (Sundet, Borren, & Tambs, 2008; Sundet, Eriksen, & Tambs, 2008).

The General Ability scores used in the present study were calculated from two different norm sets. The previous norms dated back to 1963. New norms were introduced in 1976, but not implemented until 1980. The 1980 norms were about one stanine point stricter than the norms from 1963 (for details see Sundet et al., 2004).

2.2. Study group and analyses files

A total of 1,006,681 males were registered in the data file from the National Conscript service, comprising around 90% of the total number of male births (10,025 females were excluded). 925,020 (around 92%) had General Ability scores. A great majority of the males who had General Ability scores (916,370 or 99.1%) were born between 1950 and 1985, inclusive.

Data on the parents and siblings of the conscripts were retrieved by matching the file from the National Conscript Service with data from the national statistics agency, Statistics Norway. The matched file comprised conscription year and intelligence data of the conscripts, birth year of the conscripts and the parents and siblings of the conscripts, and education data. These data enabled identification of brothers (defined as persons with the same mother), the birth rank of each brother, and the age difference between them.

The analyses were performed in two different data files. In one of them each conscript served as a record, while brother pairs served as records in the other. Conscripts with birth order higher than five were excluded. Fig. 1 shows the secular trends for the General Ability mean scores for all the male conscripts in the period 1950–1985 in a file where each conscript was a record (we have added one stanine point to the scores of the conscripts who had been tested in 1980 or later to remove the effect of the new norms), and the subfile comprising persons with at least one sibling and with birth rank orders not larger than five. The two curves almost coincide.

Fig. 1 shows that there was a quite steady and close to linear increase from the birth cohort 1950 to the birth cohort 1956. From 1956 to 1960 there was a comparatively short period of quite linearly declining means. The General Ability means were quite stable in the period from 1960 to1965, and were followed by a period with a somewhat irregular tendency but generally increasing means (1966–1975). In the birth cohort group 1976–1983 there was a quite steady decrease of the General Ability means.

In the brother file all possible brother pairs were represented with a separate record. Age difference between brothers was given in number of calendar years. Twin pairs were removed by excluding brothers born in the same calendar year.

In both the file comprising conscripts as records and the file comprising brother pairs as records the analyses were confined to conscripts belonging to exactly one of the three birth cohort groups 1950–1956, 1960–1965, and 1976–1983. The period of declining means from 1956–1960 overlapped with the previous (1950–1956) and the subsequent (1960–1965) periods. Excluding the overlapping years, the remaining period was deemed too short for meaningful analyses. The period from 1966 to 1975 was excluded from the analyses for two different reasons. First, and most importantly, the intelligence means across cohorts varied quite irregularly, especially in the 1966–1970 interval. Second; due to the change of format of the Arithmetic test in the beginning of the 1990's, conscripts born in the interval 1973–1975 were excluded. We have as far as possible kept the original General Ability scores attained from the National Conscript Service. Some of the conscripts in the 1960–1965 birth cohort group had been tested in 1980 or later, and their General Ability

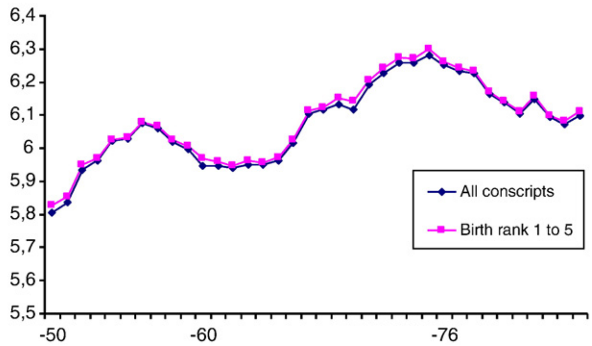

Fig. 1. Mean General Ability of all conscripts and the subgroup comprising birth ranks 1–5 in 2-child or larger families by birth year.

scores were adjusted by adding one stanine point to the original scores from the National Conscript Service.

The total number of brother pairs in the three birth cohorts 1950–1956, 1960–1965 and 1976–1983 was 69,185. Table 1 shows the number of brother pairs with General Ability scores across age differences in each of the three cohort groups.

2.3. Statistical methods

The idea behind the analyses was to investigate to what extent the secular trends in intelligence-test score means can be accounted for by changing intelligence score differences between brothers across different age-difference groups. This is done by comparing the changes in the intelligence-test means as calculated in the file where each conscript is a record to the intelligence difference between the later-born and the earlier-born brother as calculated in the brother file (comprising all the possible brother pairs as records). The critical point is the behaviour of the intelligence-test scores of the later-born brothers relative to the intelligence-test scores of the earlier-born brothers compared to the changes of the intelligence-test score means across birth years in the file with each conscript as a record. To the extent that age differences between brothers reflect the Flynn effect, it should be expected that the intelligence scores of the later-born brothers increase relative to the intelligence scores of the earlier-born brothers in the birth cohorts 1950–1956. In the period 1976–1983 there was a negative Flynn effect (Fig. 1), and we should expect that the intelligence-test score of the later-born brothers decreases relative to the intelligence-test scores of the earlier-born brothers. In the 1960–1965 birth cohorts (no Flynn effect) no effects of age differences between brothers should be observed. An all-over comparison of the relationship between the Flynn effect and age-difference effects on intelligence differences between brothers can be obtained by regressing General Ability scores on birth year in the file in which each conscript serves as a record, and comparing it with the regression coefficient obtained by regressing intelligence score difference between the later-born and the earlier-born sibling on the age difference between the brothers as calculated in the brother file.[1] To the extent that the age-difference effects between later-born and earlier-born brothers on intelligence differences between them predict the Flynn effect, these two regression coefficients should be equal, both in sign and magnitude in all three cohorts.

3. Results

Fig. 2 shows the General Ability difference between members of brother pairs (General Ability of the later-born minus the General Ability of the earlier-born) across age differences in three birth cohort groups (1950–1956, 1960–1965, and 1976–1983). Fig. 2 shows that the magnitude of the difference in General Ability between the brothers depended on the birth cohort group. In the 1950–1956 birth cohort

[1] We are indebted to Michael Mingroni for the idea of comparing the regression coefficients in the two types of files. He also kindly offered insightful comments on an early version of the present manuscript.

Table 1
Numbers and percentages (%) of brother pairs by age difference and birth cohort group.

Cohort group				
Age difference	1950–1956	1960–1965	1976–1983	Total
	N (%)	*N* (%)	*N* (%)	*N* (%)
1 year	3668 (17.8)	6132 (23.7)	2233 (9.8)	12,033 (17.4)
2 years	6215 (30.2)	8794 (34.0)	6105 (26.9)	21,114 (30.5)
3 years	4750 (23.1)	6052 (23.4)	6180 (27.2)	16,982 (24.5)
4 years	3259 (15.8)	3535 (13.7)	4049 (17.8)	10,843 (15.7)
5 years	1919 (9.3)	1379 (5.3)	2387 (10.5)	5685 (8.2)
6 years	770 (3.7)	–	1231 (5.4)	2001 (2.9)
7 years	–	–	527 (2.3)	527 (0.8)
Total	20,581	25,892	22,712	69,185

N = number of brother pairs.

group, there was a quite steady *decrease* in the General Ability difference between brothers across increasing age distances between the brothers. In the 1976–1983 cohort group, the mean General Ability difference between brothers showed a distinct *increase* across age differences. Analyses of the relationship between age differences and General Ability differences in the period with no appreciable Flynn effect (1960–1965) showed a weak and non-systematic effect of age differences on intelligence-test score differences between brothers.

Comparing Figs. 2 and 1, it can be seen that trends in the mean General Ability differences across age differences in the 1950–1956 and 1976–1983 birth cohort groups (Fig. 2) were quite closely related to the secular changes of General Ability across birth years in these three cohort groups (Fig. 1). Thus, in the period with a positive Flynn effect (1950–1956), the General Ability of the youngest brother increased relative to the General Ability of the oldest brother across increasing age distances between the brothers. In the period with decreasing means across birth years (1976–1983), the General Ability difference between brothers increased across increasing age difference between them. No consistent upward or downward trends of the General Ability difference scores across age differences were apparent between 1960 and 1965 (Fig. 2). In this period the mean General Ability remained quite stable across cohorts (Fig. 1).

The trends in General Ability means across birth years in the three cohort periods (1950–1956, 1960–1965, and 1976–

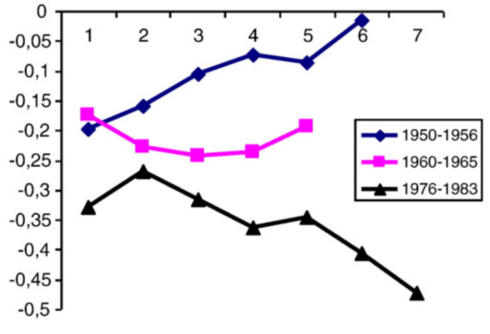

Fig. 2. Mean General Ability differences between the later-born and the earlier-born brother by age difference (in years) and birth cohort group.

1983) can be reasonably well approximated by straight lines (cf. Fig. 1). Also, the relationship between General Ability difference and age difference can reasonably be approximated by straight lines in all three birth cohort groups (Fig. 2). Thus, it is appropriate to conduct linear regression analyses in both the file with each conscript as a record and in the brother file.

In the 1950–1956 birth cohort group the (unstandardized) regression coefficient when regressing General Ability on birth year was 0.042 (corresponding to a change rate of 0.3 IQ points per year). The regression coefficient with General Ability of the later-born minus the General Ability of the earlier-born as the dependent variable and the age difference in years between the brothers as the independent variable was 0.034, i.e. the General Ability difference between the brothers decreased by 0.034 stanine points per year age difference. Thus, a large part of the year by year changes of General Ability means in the 1950–1956 cohort group could be predicted from the changes of the intelligence-test score of the later-born brother relative to the intelligence-test score of the earlier-born brother across age differences between them. In the 1960–1965 birth cohort group, regressing General Ability on birth year gave a regression coefficient very close to zero, while the regression coefficient when regressing General Ability difference on age difference was −0.014, which is not, in contrast to the other regression coefficients, significantly different from zero ($p>.10$). In the 1976–1983 birth cohort group the regression coefficient when regressing General Ability on birth year was −0.024. The regression coefficient with age difference and General Ability difference as independent variables, respectively was −0.025. The downward secular trends of the General Ability means in this cohort group (Fig. 1) could thus be almost perfectly predicted by age-difference effects.

In the brother file comprising the brothers with birth ranks from 1 to 5, the same person may appear more than once in the data file, possibly biasing the results. We have investigated this possibility by analyzing the age-difference effects including only the second-born and first-born brother. To get decent sample sizes, age differences of five years or more have been collapsed into one age group (cf. Fig. 3).

Comparing the differences in General Ability across age differences displayed in Figs. 2 and 3, and noting that only the age-difference groups 1–4 years age difference are strictly comparable, it is seen that the age-difference effects were

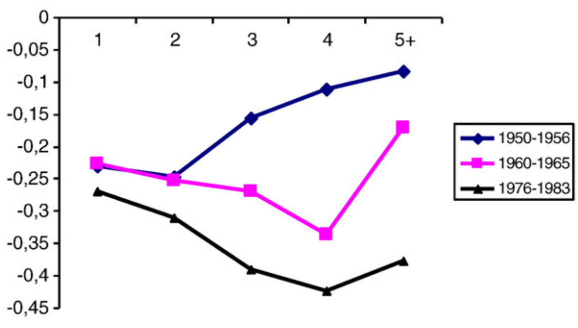

Fig. 3. Mean General Ability differences (in years) between the second-born and first-born brother by age difference and birth cohort group.

quite similar in the group comprising all possible pairs of the five earliest-born brothers, and the group comprising only the first-born and the second-born brother.

It is clear from Figs. 2 and 3 that the mean General Ability score of the later-born brother was lower than the mean General Ability score of the earlier-born brother in all the three birth cohort groups, entailing a birth order effect in Norway. This has earlier been reported by Bjerkedal et al. (2007) and Kristensen and Bjerkedal (2007) in a large subset of the present data set comprising birth cohorts from 1967. The present results extend this period back to the 1950 birth cohort. In addition, the present results indicate that the magnitude of the birth order effect depends on the magnitude and direction of the Flynn effect. In the 1950–1956 birth cohort group the first-born brother on the average scored 1.5 IQ points higher than the second-born brother. The corresponding differences in the 1960–1965 and 1976–1983 were around 2 and 2.7 IQ points, respectively.

4. Discussion

The tests used to assess the intellectual ability among Norwegian conscripts are representative of subtests regularly included in standard intelligence tests. Thus, the Arithmetic and Word Similarities subtests are similar to the Arithmetic and Vocabulary subtests in WAIS, and the Figures test was explicitly constructed to be similar to the Raven Progressive Matrices test. The General Ability score obtained by combining the scores on the three tests, correlates highly with WAIS IQ scores (Sundet, Borren, & Tambs, 2008). The General Ability scores reported in the present paper are thus quite comparable to scores obtained on standard intelligence tests. Due to a change of the norms in 1980, some of the intelligence-test scores in the 1960-1965 birth cohorts were adjusted. Otherwise, no changes of norms, contents or format of the three tests have appeared in the subgroups included in the analyses. A great majority of the conscripts have been tested at approximately the same age (between their 18th and 21st birthday), excluding possible age effects on the test scores. The secular trends of General Ability in the subgroup analyzed (the five earliest-born males, living in families comprising at least two siblings with known mothers) were virtually identical to the secular trends in the whole group of conscripts (Fig. 1). The effects of age difference seem to be quite independent of the number of brothers included in the analyses (Figs. 2 and 3).

The present results demonstrate a distinct effect of age differences on the intelligence differences between brothers in Norway. This finding is in accordance with the conclusions of Zajonc (1976), but not with the results from a Dutch study of brother pairs (Belmont et al., 1978). It may be speculated that cultural differences are involved. The present results reveal a close relationship between the Flynn effect and the effect of age differences (Figs. 1–3). During the period of secular increases of the General Ability scores (birth years 1950–1956), the General Ability scores of the later-born brother increase relative to the scores of the earlier-born, and more so the larger the age difference. During the period of secular decreases of the General Ability scores in the 1976–1983 birth cohorts, the General Ability scores of the later-born brother tend to decrease relative to the scores of the earlier-born brother. In the absence of a Flynn effect, the effects of age differences on the General Ability scores seem to be small and unsystematic.

Regression analyses confirm the impression of a close connection between secular trends in the intelligence-test scores and the age-difference effects on the intelligence differences between brothers. Indeed, the regression coefficients calculated with birth year as the independent variable and intelligence-test score as the dependent variable turned out to be quite similar to the regression coefficients with age difference between brothers as the independent variable and intelligence-test score difference between the later-born and the earlier-born brother as the dependent variable. This pattern indicates that factors causing the secular trends of intelligence scores in Norway since 1950 or so also seem to work within sibships.

The results of a recent study on Norwegian military conscripts showed that the increase of the proportion of small families at the expense of large families (a between-families factor) might explain a modest part of the Flynn effect in the cohorts born in the late 1930's to the cohorts born in the early 1950's. After the 1950's the effect of changes of family size proportions was small to negligible (Sundet, Borren, & Tambs, 2008). Perhaps different factors are at work in different time periods. This may also be the case across countries. In particular, the declines in intelligence means in the birth cohorts from the mid 1950's to around 1960 (Sundet et al., 2004), and the more recent declines in intelligence means found both in Norway (Sundet et al., 2004) and nearby Denmark (Teasdale & Owen, 2005) do not seem to be typical. Considering our lack of understanding of the factors causing the Flynn effect, it is also difficult to account for the observed declines. Sundet et al. (2004) observed that both declines to a large part seem to be due to decreasing means in the Arithmetic test. The declines in the first period may partly be due to more teaching of modern mathematics (algebra) at the expense of training in arithmetic operations, which was terminated after a few years. It may be speculated that the more recent declines may partly be due to a steadily increasing use of computers.

Also, the association between birth order and intelligence that seems to be present in data on Norwegian conscripts may not be universal. Thus, studies on US data show no systematic birth order effect (Rodgers, Cleveland, van den Oord, & Rowe, 2000; Wichman, Rodgers, & MacCallum, 2006). Bjerkedal et al. (2007), analyzing a large subset of the data used in the present paper, discussed possible reasons for different results across countries, and their arguments need not be reiterated here. The present results indicate that the birth order effect found in Norway might be conditional on the Flynn effect.

The causes of the Flynn effect are still not clear, but the predictions from the heterosis hypothesis (Mingroni, 2004, 2007) do not seem to be in accordance with the present results because the parents are fixed. Thus, the intelligence of the members of sibhips in families should not be affected differentially.

An obvious limitation of the present study is that the data material exclusively comprises males, and strictly do not generalize to the female population. Flynn (1998b) reported similar intelligence gains among male and female Israeli conscripts. The effects of age-differences on the intelligence-test scores in sibships may differ in sister-sibships and mixed sibships, however. Time of birth was given in calendar years. The calculated age differences between brothers may in some cases be slightly biased. In particular, the age gap between brothers born in consecutive calendar years is likely to be more than one year. We have meticulously tried to identify periods where no change of norms or format of the ability tests had occurred, but in the period 1960–1965 it was not possible to avoid that the General Ability scores for some persons (mainly born in the 1960 and 1961 birth cohorts) had been calculated according to different norms than the rest of the birth cohort group. Although we feel quite confident that our adjustments of the scores are adequate, the possibility of slight biases may not be completely excluded.

Acknowledgements

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