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ABSTRACT

We investigated time-related patterns in levels of cognitive performance during the period from 1970 to 1993 based on data from Swedish draft boards. The conscripts, including more than a million 18–19-year old men, had taken one of two versions of the Swedish enlistment battery (SEB67; 1970–1979 or SEB80; 1980–1993), each composed of four subtests. The results revealed significant Flynn effects, with estimated gains of 1.2–1.5 IQ-units per decade. The effect seem to hold across ability levels, even though tendencies of more pronounced effects in the lower half of the ability distribution was observed. The largest gains were for visuospatial tests (Paper Form Board and Metal Folding), with little change, even slight losses during the second sub-period, for tests of verbal knowledge (Concept Discrimination and Synonyms) and a mixed pattern for a test of technical comprehension (losses followed by gains). Finally, comparisons of trends in cognitive performance and in standing height show that the gains in cognitive performance over the years from 1980 to 1993 occurred in the absence of overall gains in height, which speaks against nutrition as the cause of the Flynn effects.

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1. Introduction

Continuous gains in cognitive test performance were observed during the last century as judged from data for groups taking the same test at different points in time. The gains were evident across a variety of cognitive-ability measures, including aggregate IQ scores (e.g. WAIS full scale IQs), measures of fluid reasoning (e.g. Ravens matrices) and spatial visualization, in US samples (e.g., Flynn, 1984), and in a variety of European nations (e.g., Flynn, 1987). In more recent studies, the effects have been demonstrated also in economically developing countries, such as Kenya (Daley, Whaley, Sigman, Espinosa, & Neumann, 2003), Sudan (Khaleefa, Sulman, & Lynn, 2009), and Brazil (Colom, Flores-Mendoza, & Abad, 2007).

The gains, known as the ‘Flynn effect’ (FE), have been attributed to a variety of factors, for example, more education (Blair, Gammson, Thorne, & Baker, 2005; Flynn, 2007; Teasdale & Owen, 1994; Williams, 1998), improved nutrition (e.g., Lynn, 1990, 1998; Martorell, 1998), more effective test taking strategies (Brand, 1987; Brand, Freshwater, & Dockrell, 1989), and smaller family sizes over cohorts (Sundet, Borren, & Tambs, 2008). Apart from the major question of what factors cause the effects, three research questions recur in the literature. First, to what extent do the gains generalize across different cognitive measures? Second, do the effects generalize across the ability distribution? Finally, did the gains cease in economically developed nations during the last decades of the 20th century?

Beginning with variability across measures, some studies suggest that substantial gains occurred for “fluid” measures, that require on-line processing of information, such as tests of reasoning (e.g. matrices) and spatial visualization, with little change for measures of acculturated knowledge, or “crystallized” intelligence (e.g., Flynn, 1987; Lynn, 1990,
2008). At the same time other sources of data indicate quite substantial gains on WAIS vocabulary (Uttl & van Alstine, 2003), and other verbal ability measures (Pietschnig, Voracek, & Formann, 2010; Rönnlund & Nilsson, 2008). Thus, even though it is often asserted that the FE is manifest on “fluid” but not “crystallized” measures, the studies have produced somewhat different outcomes.

Turning to the issue of whether the FE generalizes across the ability distribution, several studies suggest that the mean-level IQ gains were not uniform (but see Flynn, 1998; Wai & Putallaz, 2011). Instead, the mean gains were mainly driven by a reduction in the number of low performers over time. For example, a comparison of two samples of Spanish children tested 30 years apart suggest increase of 9.7 IQ points, but also that the gain decreased gradually with increasing raw scores (Colom, Lluis-Font, & Andres-Pueyo, 2005). In a similar vein, results by Teasdale and Owen (1989, 2000) suggest that the FE observed for Danish conscripts was largely attributable to a reduced number of low-end scores. A comparison of what percentile levels given raw scores on the Ravens Standard Matrices correspond to over time reveals a similar picture (Raven, 2000). A difficulty in drawing conclusions based on the last set of data is that performance approached ceiling levels, a factor considered also in other studies (e.g. Teasdale & Owen, 2000).

Finally, evidence that the FE has ceased during the last decades has been provided in a recent set of studies. First, a study based on Norwegian conscripts revealed gains up to the mid 1990s after which a tendency of decline was actually observed until 2002 (Sundet, Barlaug, & Torjussen, 2004; cf. the mid 1990s). Thus, even though it is often asserted that the FE is manifest on “fluid” but not “crystallized” measures, the studies have produced somewhat different outcomes.

Turning to the issue of whether the FE generalizes across the ability distribution, several studies suggest that the mean-level IQ gains were not uniform (but see Flynn, 1998; Wai & Putallaz, 2011). Instead, the mean gains were mainly driven by a reduction in the number of low performers over time. For example, a comparison of two samples of Spanish children tested 30 years apart suggest increase of 9.7 IQ points, but also that the gain decreased gradually with increasing raw scores (Colom, Lluis-Font, & Andres-Pueyo, 2005). In a similar vein, results by Teasdale and Owen (1989, 2000) suggest that the FE observed for Danish conscripts was largely attributable to a reduced number of low-end scores. A comparison of what percentile levels given raw scores on the Ravens Standard Matrices correspond to over time reveals a similar picture (Raven, 2000). A difficulty in drawing conclusions based on the last set of data is that performance approached ceiling levels, a factor considered also in other studies (e.g. Teasdale & Owen, 2000).

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The objective of the present study was to examine levels of cognitive test performance in the period from 1970 to 1993 in Swedish conscripts. We aimed at providing evidence in regard to the major issues above by examining performance at the level of individual subtests as well as on a general-ability factor, and by attending to potential changes in the distribution of scores over time. Based on the aforementioned Scandinavian studies, it was hypothesized that the gains would be most likely to show up on tests including a visuospatial component. In order to provide evidence in regard to the nutrition theory of the FE we, finally, compared the time-related pattern for cognitive performance with that for standing height (cf. Sundet et al., 2004).

2. Method

2.1. Participants

Records of complete cognitive data (i.e. with data for each of the individual subtests) for a total of 1065 189 men aged 18–or 19 years (22% were 19 at the time of testing), obtained from Swedish draft boards (1970–1993), were retrieved.

2.2. Measures

During the period in focus, two enlistment test batteries were used. Both batteries were administered as paper and pencil tests. Answers were given on separate answer sheets and all tests were slightly speeded. The first version of the Swedish enlistment battery (SEB), SEB67, was administered during the period from 1970 to 1979 and the second, SEB80, was in use from 1980 to 1993.

2.2.1. SEB67

This battery comprised four subtests. Instructions (40 items) involved verbally formulated instructions to make markings on the answer sheet that fulfill the conditions given by the instructions. Difficulty is varied by the complexity of the instructions and by distractive negations or conditional clauses. In some items simple numerical operations are parts of the logical sequences. The test is meant to measure the primary factor Induction, Concept Discrimination involved classification of words and included 40 items. For each item, five words were presented wherein the word that did not fit in with the others should be marked. The test was meant to measure verbal ability. Paper Form Board involved judgments of which target object out of four would be correctly put together by a set of disarranged parts of objects (25 items). Technical Comprehension involved 52 items presenting illustrated technical and physical problems (Carlstedt, 2000).

2.2.2. SEB80

In this version of the enlistment battery, the Instructions test was retained (with some improvements). Concept Discrimination was replaced by a Synonym test (40 items) intended to better measure the verbal ability factor. Paper form board was replaced by another test intended to assess spatial visualization called Metal folding (40 items). The task of the Metal folding items was to find one three-dimensional object out of four that corresponds to a two-dimensional drawing of an unfolded piece of metal. A modified version of the Technical Comprehension test (40 items) was finally included (Carlstedt, 2000. Carlstedt and Mårdberg (1993) report coefficient alphas for the SEB80 tests of .91 (Instructions), .88 (Synonyms), .89 (Metal Folding), and .79 (Technical Comprehension). The changes made from SEB67 to SEB80 indicate that we cannot study the period as one held-together series but have to divide it into two separate time periods to study the FE.
2.3. Data reduction

Raw scores were obtained for all the tests. In order to extract an index of general ability, separate principal component analyses (PCAs) were performed on the data for SEB67 and SEB80. In both cases a single factor (eigenvalue > 1) was extracted. For SEB67, the component explained 66.1% of the variance (eigenvalue = 2.64), and for SEB80 the single factor explained 71.0% of the variance (eigenvalue = 2.84). For SEB67, the loadings for the individual subtests were: .87 (Instructions), .86 (Concept Discrimination), .74 (Paper Form Board), and .77 (Technical Comprehension). The loadings for the SEB80 subtests were .89 (Instructions), .83 (Synonyms), .81 (Metal Folding), and .84 (Technical Comprehension). Factor scores of the general factor of each battery were computed using the regression option in PASW 18.

2.4. Attrition

In some of the years (1978, 1984 and 1985) there are considerable numbers of missing observations of test data. 1970, 1979 and 1983 also show numbers of observations that are lower than expected. Causes for this attrition are mainly unknown but may be the results of mistakes done in the registration and storage of data at the Swedish National Service Administration. The randomness of the attrition is also unknown. We present the results for the observations we have and omitting the years with substantially lower number of observations from the subsequent analyses did not alter any of the main outcomes.

3. Results

We will first consider the patterns of time-related changes at the level of the individual subtests. Next, we consider changes in distribution of test scores over time. Finally, we compare mean-level changes in the general ability with those for standing height.

Descriptive statistics ($M$, $SD$, skewness, kurtosis) of the subtests are given in Table 1 (1970–1979) and Table 2 (1980–1993). We can discern a tendency of higher scores over time on three out of four subtests for each of the batteries; for SEB67, minor gains are evident for Instructions and Concept Discrimination and for the Paper Form Board test, with a reversed trend for Technical Comprehension; for SEB80 there are numerical increments in level for performance over the period on the subtests with the exception of Synonyms.

In order to allow meaningful comparisons of the rate of changes between the tests, the data were transformed into IQ scores ($M = 100$, $SD = 15$) based on data for the first years of each period (i.e. 1970 and 1980). The results are portrayed in Fig. 1 (SEB67; 1970–1979) and Fig. 2 (SEB80; 1980–1993).

Beginning with the period from 1970 to 1979 (Fig. 1), there were minor gains for Concept Discrimination and Instructions, but quite substantial gains for the Paper Form Board test of about 4 IQ points. Finally, there was a continuous drop across the period for Technical Comprehension. Estimates of IQ change/decade derived from simple regression analyses ($p < .001$) where the unstandardized regression coefficient (indicating annual gain) was multiplied by ten were: 0.5 IQ points for Instructions, 1.9 IQ points for Concept Discrimination, 4.2 IQ points for Paper Form Board and $-2.4$ IQ points for Technical Comprehension. The corresponding estimate for the general ability (GA) was 1.3 IQ points per decade.

Turning to Fig. 2, we see that from 1980 to 1993, Metal Folding, Instructions, and Technical Comprehension showed a mean increase of up to about 3 IQ points. However, performance on the Synonym test declined by nearly 2 IQ points. Estimates of change per decade, derived from simple regression analyses were: Instructions: 1.7; Synonyms: $-0.5$; Metal Folding: 2.7; Technical Comprehension: 1.8. For the GA factor the corresponding value was 1.6 IQ-points/decade.

Next, we considered whether the gains observed across the majority of measures appeared across the ability distribution. To this end, we summed the scores on the three subtests for which a gain was evident (i.e. for each version of the test battery) and examined the distribution of gains by considering differences from the first to last year in each series at given percentile levels ($P5$–$P95$).

The results are provided in Table 3. As can be seen, all contrasts were positive, with an indication that the gains were more pronounced in the bottom-half as compared with the top-half of the distribution ($M = 2.33$ and $M = 1.00$, respectively for the bottom- and upper-half of the distribution across the 1970–1979; $M = 3.67$ and $M = 2.33$ for the bottom- and upper-half of the distribution in the period 1980–1993). Analyses of the GA factor revealed similar patterns.

In order to compare the gains on the GA factor with mean changes in body height, both measures were transformed to $z$-scores. As before, the data ($M$, $SD$) for the first year of each

<table>
<thead>
<tr>
<th>Test year</th>
<th>Instructions</th>
<th>Concept discrimination</th>
<th>Paper form board</th>
<th>Technical comprehension</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M$</td>
<td>$SD$</td>
<td>Skew/kurt</td>
<td>$M$</td>
<td>$SD$</td>
<td>Skew/kurt</td>
</tr>
<tr>
<td>1970</td>
<td>24.51 (5.48)</td>
<td>−0.45/0.48</td>
<td>22.85 (6.36)</td>
<td>−0.26/0.29</td>
<td>13.72 (3.92)</td>
</tr>
<tr>
<td>1971</td>
<td>24.70 (5.31)</td>
<td>−0.41/0.38</td>
<td>22.86 (6.25)</td>
<td>−0.27/0.46</td>
<td>13.81 (3.90)</td>
</tr>
<tr>
<td>1972</td>
<td>24.81 (5.40)</td>
<td>−0.39/0.43</td>
<td>22.78 (6.17)</td>
<td>−0.24/0.39</td>
<td>13.87 (3.90)</td>
</tr>
<tr>
<td>1973</td>
<td>24.73 (5.41)</td>
<td>−0.40/0.41</td>
<td>22.86 (6.04)</td>
<td>−0.25/0.48</td>
<td>13.90 (3.92)</td>
</tr>
<tr>
<td>1974</td>
<td>25.02 (5.52)</td>
<td>−0.39/0.40</td>
<td>23.37 (5.97)</td>
<td>−0.26/0.51</td>
<td>14.09 (3.89)</td>
</tr>
<tr>
<td>1975</td>
<td>25.02 (5.44)</td>
<td>−0.39/0.40</td>
<td>23.25 (5.88)</td>
<td>−0.26/0.58</td>
<td>14.18 (3.94)</td>
</tr>
<tr>
<td>1976</td>
<td>24.69 (5.36)</td>
<td>−0.36/0.35</td>
<td>23.53 (5.93)</td>
<td>−0.29/0.61</td>
<td>14.34 (3.96)</td>
</tr>
<tr>
<td>1977</td>
<td>24.76 (5.42)</td>
<td>−0.36/0.35</td>
<td>23.54 (5.87)</td>
<td>−0.28/0.58</td>
<td>14.45 (3.93)</td>
</tr>
<tr>
<td>1978</td>
<td>24.86 (5.48)</td>
<td>−0.32/0.37</td>
<td>23.51 (5.98)</td>
<td>−0.23/0.46</td>
<td>14.78 (3.95)</td>
</tr>
<tr>
<td>1979</td>
<td>24.78 (5.50)</td>
<td>−0.35/0.34</td>
<td>23.30 (5.76)</td>
<td>−0.19/0.40</td>
<td>14.61 (3.95)</td>
</tr>
</tbody>
</table>
Fig. 1 shows the patterns of changes for cognitive performance during the period from 1970 to 1993 based on records of the Swedish draft board for 18/19-year old men. As can be seen, gains in GA were paired with increments in height. However, as conveyed by Fig. 4, the gains in the GA factor over the second time period (1980–1993) were evident in the absence of overall gains in height. Finally, for the former period (Fig 1) it is interesting to note that a comparison of height corresponding to that for cognitive performance (Table 3) revealed a difference (gain) of 1 cm throughout the distribution (i.e. P5–P95).

4. Discussion

The objective of the study was to examine the patterns of changes in cognitive performance during the period from 1970 to 1993 based on records of the Swedish draft board for 18/19-year old men.

Overall, the results confirm a Flynn effect (FE), with a rate of gain of about 1.5 IQ points per decade on a general ability factor. This estimate is about half of that observed by Flynn (1984) over the period from 1932 to 1978, but comparable to the magnitude of gains observed in Norway over the same time period. Also, the estimate is in line with previous ones, based on our previous study involving Swedish samples (Rönnlund & Nilsson, 2008). Of further interest, the gains appeared to be gradual over the period. Also, even though a change in the composition of the battery is a factor to consider, the gain for our subset of data for 1980–1993 was at least as large as that for the foregoing period (1970–1979). Thus, in regard to the major question of whether the Flynn effect progressed, the present findings show that the FE was undiminished in magnitude up to the mid 1990s, with no indication of a deceleration in the rate of gain. It remains to be demonstrated whether more recent years have been characterized by stable or even declining levels of performance for these age groups, as indicated by prior Scandinavian studies (Sundet et al., 2004; Teasdale & Owen, 2005), or whether the gains have progressed further, as demonstrated by recent data for other nations (e.g., Lynn, 2008; te Nijenhuis, Cho, Murphy, & Lee, 2012). Even though data for more recent years were not available to us at present, and

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Table 2

<table>
<thead>
<tr>
<th>Test year</th>
<th>Instructions</th>
<th>Synonyms</th>
<th>Metal folding</th>
<th>Technical comprehension</th>
<th>N</th>
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<td>M (SD) Skew/kurt</td>
<td>M (SD) Skew/kurt</td>
<td>M (SD) Skew/kurt</td>
<td>M (SD) Skew/kurt</td>
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<td>1980</td>
<td>24.39 (7.73) $-0.35/-0.50$</td>
<td>24.81 (6.73) $-0.51/0.08$</td>
<td>21.30 (8.16) $-0.05/-0.85$</td>
<td>24.43 (5.71) $-0.28/0.10$</td>
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<td>1981</td>
<td>24.50 (7.70) $-0.37/-0.49$</td>
<td>24.78 (6.66) $-0.53/0.13$</td>
<td>21.42 (8.25) $-0.02/-0.88$</td>
<td>24.68 (5.71) $-0.31/0.18$</td>
<td>54196</td>
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<td>1982</td>
<td>24.36 (7.64) $-0.33/-0.50$</td>
<td>24.45 (6.65) $-0.53/0.13$</td>
<td>21.36 (8.20) $-0.03/-0.87$</td>
<td>24.45 (5.63) $-0.28/0.16$</td>
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<tr>
<td>1983</td>
<td>24.63 (7.58) $-0.35/-0.48$</td>
<td>24.66 (6.54) $-0.53/0.16$</td>
<td>21.89 (8.17) $-0.03/-0.86$</td>
<td>24.83 (5.61) $-0.30/0.17$</td>
<td>54978</td>
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<td>1984</td>
<td>24.42 (7.57) $-0.33/-0.50$</td>
<td>24.50 (6.46) $-0.50/0.03$</td>
<td>21.98 (8.14) $-0.04/-0.86$</td>
<td>24.94 (5.52) $-0.26/-0.06$</td>
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<td>1985</td>
<td>24.44 (7.45) $-0.31/-0.48$</td>
<td>24.23 (6.41) $-0.42/-0.03$</td>
<td>21.97 (8.06) $-0.03/-0.86$</td>
<td>24.79 (5.45) $-0.22/-0.10$</td>
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<td>1986</td>
<td>24.68 (7.52) $-0.37/-0.44$</td>
<td>24.33 (6.42) $-0.52/0.16$</td>
<td>22.27 (8.11) $-0.08/-0.85$</td>
<td>24.97 (5.56) $-0.28/0.00$</td>
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<tr>
<td>1987</td>
<td>24.78 (7.57) $-0.37/-0.43$</td>
<td>24.50 (6.43) $-0.58/0.25$</td>
<td>22.46 (8.10) $-0.09/-0.86$</td>
<td>25.04 (5.53) $-0.28/0.02$</td>
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<td>1988</td>
<td>24.79 (7.54) $-0.37/-0.44$</td>
<td>24.36 (6.35) $-0.53/0.17$</td>
<td>22.45 (8.06) $-0.09/-0.85$</td>
<td>24.99 (5.51) $-0.28/0.00$</td>
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<td>1989</td>
<td>25.25 (7.51) $-0.42/-0.38$</td>
<td>24.71 (6.34) $-0.55/0.17$</td>
<td>22.90 (8.11) $-0.14/-0.84$</td>
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<td>25.10 (7.54) $-0.38/-0.42$</td>
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<td>24.99 (5.49) $-0.30/0.05$</td>
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<td>1991</td>
<td>25.35 (7.55) $-0.43/-0.37$</td>
<td>24.61 (6.24) $-0.56/0.26$</td>
<td>23.06 (8.11) $-0.16/-0.83$</td>
<td>25.21 (5.56) $-0.31/0.04$</td>
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<tr>
<td>1992</td>
<td>25.45 (7.47) $-0.42/-0.38$</td>
<td>24.41 (6.23) $-0.56/0.30$</td>
<td>22.95 (8.05) $-0.15/-0.83$</td>
<td>25.43 (5.60) $-0.29/-0.03$</td>
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<tr>
<td>1993</td>
<td>25.39 (7.46) $-0.43/-0.34$</td>
<td>24.16 (6.18) $-0.54/0.29$</td>
<td>22.75 (8.03) $-0.13/-0.83$</td>
<td>25.36 (5.64) $-0.28/0.01$</td>
<td>36000</td>
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</table>
although changes in Swedish conscription procedure, apart from another major change in the test battery (Carlstedt, 2000), resulted in a progressive larger selection of test takers during the first decade of the 21st century, these and other sources of data are clearly worth investigating further.

A second main question concerned the possible variation of Flynn effects across tests. Apart from the gains on a general factor, a closer examination indeed showed that individual subtests varied in regard to time-related patterns. In line with our hypothesis, measures reflecting visuospatial abilities showed substantial gains (Sundet et al., 2004; Teasdale & Owen, 2000). By contrast, measures involving verbal comprehension showed little change, and even some decline, in case of the Synonyms test (1980–1993). As such, the results provide support of the notion of a relatively small time-/cohort-related variation for crystallized tests. Our previous findings of quite marked gains over cohorts on such measures (Rönnlund & Nilsson, 2008) possibly reflect the fact that the results were mainly based on cohorts born earlier than those involved at present and perhaps the fact that they were older at time of testing; it may be hypothesized that with time the opportunity of learning, beyond that offered in school, has increased. Thus, the FE for crystallized tasks, might have decelerated and ceased at a time (around 1980) in which the gains in other measures (e.g., spatial ability measures) continued (cf. also Emanuelsson & Svensson, 1990). Our finding of an initial drop (1970–1979) in Technical Comprehension, but a gain thereafter (1980–1993) is puzzling. In the absence of more precise information of the revision that the test underwent from the first to the second version of the enlistment battery we can only speculate that a factor such as earlier changes in educational practice in regard to teaching of item-relevant knowledge (e.g. such that the items in the SEB67 became obsolete over time) could be involved. Taken together, the present findings indicate that the Flynn effect was more marked for fluid/spatial tests than for crystallized tests, in line with several prior studies involving younger adults.

As reported in the introduction, several, but not all, studies, suggest that the FE is more attenuated in the bottom half of the ability distribution, with no or only minor gains in the upper half of the ability distribution (e.g., Colom et al., 2005; Teasdale & Owen, 1989, 2000). In the present study, there was a similar tendency, in particular for the 1970–1979 period. At the same time, there was evidence of a shift upwards in scores at least up to the 95th percentile level. Thus, in regard to the issue of whether the Flynn effect generalizes across the ability distribution, the present observations suggest that the effects were not entirely due to a decreased variance in the lower part of the ability distribution. At this point it should also be acknowledged that the trend of such a decreased variance observed here and in other studies could reflect glass ceilings in some of the individual tests, indicating that the effects could be quite general in regard to intelligence level, despite this tendency.

Finally, our comparison of gains in test performance and height were of theoretical interest in that that gains in cognitive test performance continued during a period characterized by no overall changes in height (1980–1993), something which speaks against nutrition as the cause of the present FEs. Moreover, gains in height observed during the preceding period (1970–1979), unlike the cognitive gains, appeared to be uniform across the distribution, which is difficult to reconcile with the theory that both types of gains reflect a common nutrition factor (cf. also Sundet et al., 2004, who actually found larger height gains in the upper half). Thus alternative explanations of the FE must be considered.
In regard to educational attainment in Sweden, it is interesting to noted that in the early 1970s, around 60% of Swedish 16- and 17-year olds took part in forms of upper-secondary schools and that the rate of direct conversion from lower- to upper-secondary school showed increments from 65% in 1975, 80% in 1980 to about 90% in the early 1990s (Skolverket, 2008). Hence, unlike the trend for height, trends in educational attainment at least fulfill the criterion that they covary with the trends in mean cognitive performance. A general increase in environmental complexity (e.g., Schooler, 1998), possibly exerting a specific influence on visuospatial tasks is a further factor to consider in explaining the patterns of time-related changes observed at present.

References


