What has caused the Flynn effect? Secular increases in the Development Quotients of infants

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ABSTRACT

Results of five studies show that during the second half of the twentieth century there were increases in the Development Quotients (DQs) of infants in the first two years of life. These gains were obtained for the Bayley Scales in the United States and Australia, and for the Griffiths Test in Britain. The average of 19 data points is a DQ gain of approximately 3.7 DQ points per decade. Similar gains of approximately 3.9 IQ points per decade have been present among preschool children aged 4–6 years. These gains are about the same as the IQ gains of school age students and adults on the Wechsler and Binet tests. This suggests that the same factor has been responsible for all these secular gains. This rules out improvements in education, greater test sophistication, etc. and most of the other factors that have been proposed to explain the Flynn effect. It is proposed that the most probable factor has been improvements in pre-natal and early post-natal nutrition.

Keywords:
- Development Quotients
- Bayley Scales
- Griffiths Test
- Flynn effect
- Nutrition
- IQ

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1. Introduction

This paper has three objectives. First, to show that the secular increase of intelligence known as the Flynn effect has also occurred in the Developmental Quotients (DQs) of infants in the first two years of life. Second, to consider the implications of this for theories of the causes of the Flynn effect. Third, to propose that improvements in pre-natal and early post-natal nutrition are the most probable factor responsible for the increases in DQs and IQs.

It has become well established that the intelligence of children and adults has increased in a number of countries during the last 80 years or so. An early study by Tuddenham Tuddenham (1948) reported that the IQ of American conscripts increased by 4.4 IQ points a decade over the years 1917–1943. Subsequent studies confirmed that IQ increases have occurred in other countries including Scotland, England, Japan and several countries in continental Europe (Scottish Council for Research in Education, 1949; Cattell, 1950; Flynn, 1984, 1987, 2005).
2007; Lynn & Hampson, 1986). These increases have become known as the Flynn effect. The rate of increase of IQs in the United States measured by the Wechsler and Binet tests from 1932 to 2001 has been approximately 3.1 IQ points a decade (Flynn, 2007, p.184).

The cause or causes of these increases have posed a major problem for intelligence researchers. Eight principal theories have been advanced to explain them. These are (1) Improvement in education has been the most favored theory. This was proposed by Tuddenham (1948, p.56): “the superior performance of the World War II group can be accounted for largely in terms of education”. Flynn has recorded that when he began working on the effect, he canvassed expert opinion and recorded that “scholarly correspondents of high competence (H.J. Eysenck, J.C. Loehlin, D. Zeaman) have offered two possible causes of IQ gains over time, increased test sophistication and a rising level of educational achievement” (Flynn, 1984, p. 47). In his latest discussion Flynn (2007) continues to endorse the improvement in education theory ("science has engendered a sea change ... formal education played a proximate role"). Many others have favored the improvement in education theory of the Flynn effect including Teasdale and Owen (1994, p.333), Jensen (1998, p.324), Meisenberg, Lawless, Lambert, and Newton (2006, p. 273), Weede and Kampf (2002, p.365), Flieiller (1996, 1999, p.1056), Greenfield (1998), Garlick (2002) and Blair, Camson, Thorne, and Baker (2005).

(2) Improved test sophistication. This was also advanced by Tuddenham (1948) and by the experts from whom Flynn sought advice in 1984. This theory has also been endorsed by endorsed by Brand (1987) and Jensen (1998, p.327) who writes of “increasing test wisdomness from more frequent use of tests”.

(3) The greater complexity of more recent environments providing greater cognitive stimulation arising from, e.g. television, media and computer games. This theory has been advanced by Schooler (1998) and a number of others: “no-one really knows the causes of the Flynn effect; computer games have always been my favourite candidate” (Wolf, 2005, p.15); “growing exposure to and awareness of the kinds of problems found in intelligence tests is enough to account for the small increases observed” (Rabbitt, 2006, p. 674); “today’s visual world offers children mazes and games on the backs of cereal boxes and on placemats at fast food restaurants in addition to their omnipresence on the computer” (Barnett & Williams, 2004); “television and other mass media may have left their mark” (Elley, 1969); “wider exposure to mass media” (Jensen, 1998, p.326).

(4) Improvements in child rearing. This theory was advanced by Elley (1969) in an early report of the Flynn effect in New Zealand: “better educated parents have more enlightened views on child rearing”. Flieiller (1996) who reports a Flynn effect in France endorses this theory: “ better child rearing practices are a partial explanation for the increase in children’s scores on intelligence tests”.

(5) More confident test taking attitudes. This theory has been advanced by Brand (1987) and Brand, Freshwater, and Dockrell (1989), who propose that increasing liberalism, permissiveness and risk taking promote speed and guessing, which in turn increase test scores.

(6) The “individual multiplier” and the “social multiplier” theories have been proposed by Dickens and Flynn (2001) and elaborated by Flynn (2007). The concept of the “individual multiplier” is that the intelligent have a thirst for cognitive stimulation and this increases their intelligence through positive feedback. The “social multiplier” posits “that other people are the most important feature of our cognitive development and that the mean IQ of our social environs is a potent influence on our own IQ” (Flynn, 2007). This leads Flynn to predict that children brought up in a university town should have higher intelligence than those without this advantage, because the high intelligence of the professors will enhance the intelligence of the population.

(7) Improvements in nutrition. This theory has been advanced by Lynn (1990, 1993, 1998), who has pointed out that nutrition affects intelligence and that the quality of nutrition has improved over the course of the twentieth century and has been responsible for increases in height and brain size of about the same magnitude as have occurred for intelligence. This theory has been endorsed as one causal factor by Arija et al. (2006), Colom, Lluis-Font, and Andres-Pueyo (2005), and by Jensen (1998, p.325).

(8) Genetics: throughout the twentieth century there has been some dysgenic trend in the economically developed nations, i.e. a tendency for an inverse relation between intelligence and fertility. For this reason a contribution of genetic factors to explain the Flynn effect has generally been ruled out. However, Jensen (1998, p.327) has suggested that the genetic factor of heterosis (hybrid vigor) could have contributed to the Flynn effect. Heterosis results from the mating of two persons from different ancestral lines, and Jensen argues this has probably increased in the United States as a result of immigration from many different countries. Further arguments for the heterosis theory have been advanced by Mingroni (2004, 2007).

2. Secular increases in the Development Quotients of infants

We now examine studies that have shown that during the second half of the twentieth century there were increases in the Development Quotients of infants in the first two years of life. There are two widely used tests for the measurement of the development of infants for which an “infant Flynn effect” has been recorded. These are the Bayley Scales, first constructed and standardized in the United States in the 1930s, restandardized in 1959 and again in 1991 (Bayley, 1933, 1936, 1965, 1993); and the Griffiths Test, constructed and standardized in Britain in 1950 (Griffiths, 1954). These tests are scored to give Developmental Quotients (DQs) analogous to the IQs of children that are obtainable from the age of three years and upwards.

The Bayley Scales provide measures of Motor Development and Mental Development. The Motor Scale measures the ages at which infants achieve motor control of things like holding up their heads, sitting up, standing, walking, jumping, etc. The Mental Scale measures the ages at which infants pay attention, display curiosity, utter their first words, respond to requests, name objects, use pronouns, etc. The two scales are correlated at 0.44 in a sample tested by Bayley (1993); at 0.42 in a sample tested by Black, Hess, and Berenson-Howard (2000); and at 0.50 among whites and 0.60 among blacks in samples tested by Bromman, Nichols, and Kennedy (1975).

The first report of a secular increase in the Development Quotients of infants is Bayley’s (1965) study of a comparison of infant development on her tests first normed in 1933–1936
and on a revised version of these tests for which norms were collected in 1959. She noted that the infants born around 1958–59 were advanced in the first two years of life compared with those born approximately 35 years earlier. However, because the second version of the test differed from the first by the addition of some more items, it is not possible to quantify the rate of secular increase in the developmental quotients.

There have been four studies that have shown secular increases in the Development Quotients of infants measured by the Bayley Scales that can be quantified. The results of these are summarized in Table 1. The data set out in the table show the dates of the two administrations or standardizations, the numbers in the samples, the mean ages of the infants in months, the secular gains in DQs, the rates of gain in DQ points per decade, and the references. Rows 1 and 2 give results comparing the norms for the Bayley Scales collected from a representative nationwide American sample in 1959 with the results obtained by a representative sample of 305 infants aged 12 months in North Carolina in 1980. The 1980 sample obtained DQs of 107.0 on the Motor Scale and 110.2 on the Mental Scale, representing gains of 3.3 and 4.9 DQ points per decade, respectively, for the two scales.

Rows 3 and 4 gives results for the Bayley Scales 1 and 2 (1966 and 1991; different versions of the test) administered to a sample of 200 infants. The sample obtained higher means on the first version of the test by 10.1 (Motor) and 11.8 (Mental) DQ points, representing gains of 3.2 and 3.4 DQ points per decade, respectively, for the two scales.

Rows 5 and 6 give results for the Bayley Scales 1 and 2 administered to infants aged 6 months and shows higher means on the first version of the test by 7.9 and 8.1 for Motor and Mental DQs, representing gains of 2.2 and 2.3 DQ points per decade, respectively. Rows 7 and 8 give results from the same study for infants aged 20 months and show gains of 10.4 and 10.9 on the Motor and Mental Scales, representing gains of 3.0 and 3.1 DQ points, respectively.

Row 9 gives results for the Bayley Mental Scales 1 and 2 given to infants in Australia and shows a gain of 18 DQ points representing a gain of 5.8 DQ points per decade.

The mean rate of gain for the four data sets of the Motor Scales is 2.9 DQ points per decade and for the four data sets of the Mental Scales in the same studies is 3.4 DQ points per decade. The Australia study shows a larger gain on the Mental Scales of 5.8 DQ points per decade. The mean gain for all 9 studies of the Bayley Scales is a gain of 3.5 DQ points per decade.

There have also been secular gains of the DQs of infants in Britain measured by the Griffiths Test. This test contains five scales designated Motor, Personal–Social, Hand and Eye, Hearing and Speech, and Performance, described as mental development. Norms were first collected in 1949 and new norms for infants aged 6 months and 18 months were collected in 1980. The results are shown in Table 2. There are five rates of gain for infants aged 6 months which show an average gain of 2.8 DQ points per decade, and a further five rates of gain for infants aged 18 months which show an average gain of 2.1 DQ points per decade. The ten comparisons show a mean secular gain of 2.45 DQ points per decade.

There do not appear to be any systematic differences in the magnitude of the gains for motor and mental abilities, for different ages, or for the United States compared with Britain, although the gain in Australia has been somewhat greater. To obtain a best estimate of the secular increases of DQs, the results of the five studies are averaged. This gives a gain of 3.7 DQ points per decade.

### 3. Implications of the secular increase of DQs

This rate of the gain in the DQs of infants aged 6–22 months is almost identical to the rate of gain of the IQs of preschool children aged 4–6 years. Fourteen studies of these are given by Flynn (1984) and the average of these is a gain of 3.9 IQ points per decade. These rates of gain are also close to the 3.1 IQ points per decade increase of IQs of school aged children and adults assessed with the Wechsler and Binet tests calculated by Flynn (2007, p.184) from numerous studies in the United States. The differences between these gains are not statistically significant and these gains should be regarded as the same. Gains in preschool children aged 3 to five and a half years old have also been reported in France over the years 1921–2001 (Bocerean, Fischer, & Flieller, 2003).

The presence of gains of approximately equal magnitude in the DQs of infants, the IQs of preschool children and the IQs of school aged children and adults poses problems for most of the theories of the causes of the Flynn effect summarized in the introduction. It is evident that the most favored theory — improvements in education — cannot have caused or even contributed to the increases in the DQs of infants and the IQs of preschool children. It may also be doubted whether the increases in the DQs of infants and the IQs of preschool children can be explained by increased test sophistication that was advanced by the experts from whom Flynn sought advice in

<table>
<thead>
<tr>
<th>Scale</th>
<th>Dates</th>
<th>N</th>
<th>Age (months)</th>
<th>Gain</th>
<th>Gain per decade</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>1959–80</td>
<td>305</td>
<td>12</td>
<td>7.0</td>
<td>3.3</td>
<td>Campbell et al., 1986</td>
</tr>
<tr>
<td>Mental</td>
<td>1959–80</td>
<td>306</td>
<td>12</td>
<td>10.2</td>
<td>4.9</td>
<td>Campbell et al., 1986</td>
</tr>
<tr>
<td>Motor</td>
<td>1959–90</td>
<td>200</td>
<td>21</td>
<td>10.1</td>
<td>3.2</td>
<td>Bayley, 1993</td>
</tr>
<tr>
<td>Mental</td>
<td>1959–90</td>
<td>200</td>
<td>21</td>
<td>11.8</td>
<td>3.4</td>
<td>Bayley, 1993</td>
</tr>
<tr>
<td>Motor</td>
<td>1959–94</td>
<td>41</td>
<td>6</td>
<td>7.9</td>
<td>2.2</td>
<td>Black et al., 2000</td>
</tr>
<tr>
<td>Mental</td>
<td>1959–94</td>
<td>41</td>
<td>6</td>
<td>8.1</td>
<td>2.3</td>
<td>Black et al., 2000</td>
</tr>
<tr>
<td>Motor</td>
<td>1959–94</td>
<td>46</td>
<td>20</td>
<td>10.4</td>
<td>3.0</td>
<td>Black et al., 2000</td>
</tr>
<tr>
<td>Mental</td>
<td>1959–94</td>
<td>46</td>
<td>20</td>
<td>10.9</td>
<td>3.1</td>
<td>Black et al., 2000</td>
</tr>
<tr>
<td>Mental</td>
<td>1959–90</td>
<td>97</td>
<td>22</td>
<td>18.0</td>
<td>5.8</td>
<td>Tasbihsazan et al., 1997</td>
</tr>
</tbody>
</table>

<p>| Table 2 |
| SECULAR GAINS ON THE BAYLEY SCALES OF INFANT DEVELOPMENT IN THE UNITED STATES AND AUSTRALIA |</p>
<table>
<thead>
<tr>
<th>Scale</th>
<th>N</th>
<th>Age (months)</th>
<th>Gain</th>
<th>Gain per decade</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>326</td>
<td>6</td>
<td>10.7</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Personal–social</td>
<td>326</td>
<td>6</td>
<td>12.9</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Hearing–speech</td>
<td>326</td>
<td>6</td>
<td>7.7</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Eye–hand</td>
<td>326</td>
<td>6</td>
<td>5.8</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Performance</td>
<td>326</td>
<td>6</td>
<td>5.8</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Motor</td>
<td>121</td>
<td>18</td>
<td>10.8</td>
<td>3.5</td>
<td></td>
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<tr>
<td>Personal–social</td>
<td>121</td>
<td>18</td>
<td>5.7</td>
<td>1.8</td>
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<tr>
<td>Hearing–speech</td>
<td>121</td>
<td>18</td>
<td>2.7</td>
<td>0.9</td>
<td></td>
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<tr>
<td>Eye–hand</td>
<td>121</td>
<td>18</td>
<td>6.7</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Performance</td>
<td>121</td>
<td>18</td>
<td>7.1</td>
<td>2.3</td>
<td></td>
</tr>
</tbody>
</table>
carried out in 1968 and 1971 found virtually no evidence of malnutrition in British children (Darke, Disselduff, & Try, 1980). Extensive malnutrition in the United States in the 1930s was reported by Palmer (1935). Some of the best evidence for the improvement of nutrition that has taken place during the twentieth century comes from Sweden where studies of the nutritional intakes of children aged 4–13 years were carried out in 1930, 1967 and 1980 (Persson, Samuelson, & Sjolin, 1989). The authors state that “in 1930 dietary habits were characterized by lack of variation and an insufficient intake of vitamins and iron” (p.867) and that 70–90% of children had anaemia. In the 1967 study of 1411 children only one case of iron deficiency was found, and in the 1980 study there were none.

Iodine is an important nutrient and deficiencies of it impair both infant Development Quotients and intelligence. Severe iodine deficiency produces cretinism, a form of severe mental retardation, while mild iodine deficiency reduces intelligence within the normal range (Stanbury, 1994). In the nineteenth and early twentieth centuries there was widespread prevalence of iodine deficiency in Europe and the United States, shown by the high prevalence of goitre and cretinism. During the course of the twentieth century iodine deficiency declined, leading to lower prevalence of goitre and cretinism and in a reduction of low IQs caused by iodine deficiency and hence an increase in IQs. In the United States goitre was present in 30.3% of men registering for military service in Northern Michigan in 1918 (Dunn, 1994), while by the end of the twentieth century goitre was virtually unknown in the United States.

From around 1920 improvements in nutrition resulting from rising living standards and improved medical care have brought about increases in height of approximately the same magnitude as for DQs (approximately one standard deviation over 50 years). These increases in height have been found in a number of countries including Britain (Chinn & Rona, 1987; Alberman, Filakti, Williams, & Evans, 1991), China (Ji & Ohswara, 1993), Japan (Tsuzaki, Matsuo, Ogata, & Osano, 1989), the Netherlands (Van Wieringen, 1978; Roede & Van Wieringen, 1985) and Sweden (Cernerud, 1993). There is a widespread consensus that the secular increases that have taken place in height have been principally due to improvements in nutrition. They have also been attributed to the reduction of diseases but this can be subsumed under improvements in nutrition because the effect of diseases on growth is to reduce the absorption of nutrients (Alberman et al., 1991; Roede & Van Wieringen, 1985; Tsuzaki et al., 1989).

The quality of pre-natal nutrition is a determinant of the birth weight of infants (Naeve, Diener, & Dellinger, 1969). The improvements in nutrition during the twentieth century have brought about increases in birth weights, e.g. during the period 1974–1999 in Sweden, Norway, Iceland, Finland, Hungary, England, Scotland, and the United States (Rooth, 2003). Numerous studies have found that giving nutritional supplements to poorly nourished pregnant women increases the birth weight of their babies (e.g. Klein, Arenales, 

1984, or by the greater complexity of more recent environments such as television and the media, experience with computer games, better child rearing practices, more confident test taking attitudes, or by the individual and the social multipliers proposed by Dickens and Flynn (2001). If these factors have had an effect on the gains, the gains should be minimal among infants and preschool children, and increase progressively up to adulthood as the effects had cumulative impact.

The most straightforward explanation for the same rates of gain of the DQs of infants, the IQs of preschool children, and the IQs of older children and adults is that the same factor or factors have been responsible for both. These factors must be operating before the age of 6–12 months. This points to improvements in nutrition and the genetic factor of heterosis (hybrid vigor) as possible candidates responsible for the Flynn effect. There are three reasons why heterosis is unlikely to be a significant factor. These are (1) although heterosis has probably increased in the United States as a result of immigration from many different countries, as Jensen (1998, p.327) suggests, this would have been much weaker in Europe where immigrants have been largely Africans and South Asians and there has been little inter-mating between these and indigenous populations, yet the Flynn effect for IQs and DQs has been just as strong in Europe; (2) there were virtually no immigrants in Europe before 1950, yet the IQ increases in Europe have been the same as in the United States; (3) the few studies that have investigated the effect of heterosis on intelligence have shown that it has little positive effect; Nagoshi and Johnson (1987) reported that the children of European–Asian marriages in Hawaii had an average 2 IQ point advantage on 15 tests. This would not have made much contribution to the 27 IQ point increase in IQ that has been recorded in the United States over the last eighty or so years (1917–2001). Furthermore, the heterosis arising from the European–Asian marriages reported by Nagoshi and Johnson (1987) involves a greater degree of hybrid vigor than marriages between Europeans. Hence the contribution of heterosis to the Flynn effect for DQs and IQs in the United States, Europe and Australia must have been negligible.

4. Improvements in nutrition

We are left by default with improvements in the quality of pre-natal and early post-natal nutrition as the most probable factor responsible for the secular increases in the DQs of infants and IQs of children and adults. However, this is not simply a conclusion by default. There is considerable positive evidence that supports the improvements in nutrition theory of the Flynn effect on both DQs and IQs. This is as follows.

(1) The quality of nutrition improved in economically developed countries during the twentieth century. For instance, in Britain a survey carried out in 1930 by the Board of Education (1931) found that 87.5% of children had symptoms of rickets, a symptom of vitamin D deficiency, while by the end of the twentieth century virtually no British children had any signs of rickets. In the mid–1930s a survey of the diet of the British population concluded that at least half were obtaining insufficient vitamins and minerals and 90% were obtaining insufficient calcium (Orr, 1936). Surveys
6. The effect of the quality of post-natal nutrition on DQs is confirmed by studies in which infants fed by breast milk or nutritionally enhanced formula milk for the first month of life register greater gains in weight, head circumference and DQs at the age of 18 months, as compared with those fed on standard formula milk (Lucas, Morley and Cole, 1998). Breast milk contains nutrients not present in formula milk likely to enhance the development of the nervous system including long-chain lipids and more iron.

7. The improvements in nutrition during the twentieth century have brought about increases in the head size of infants. In Britain the average head circumference of 1 year old infants increased by approximately 1.5 cm over the period from approximately 1930–1985 (Cole, 1994; Ounsted, Moar, & Scott, 1985; Whitehead & Paul, 1988). Similar increases in the brain size of infants have been reported in Germany (Kretschmann, Schleicher, Wingert, Zilles, & Loblich, 1979). These are increases of approximately 1 standard deviation and of the same order as the secular increases that have occurred for DQs, IQs and for height. Head size and brain size are correlated at approximately 0.8 (Brandt, 1978), so head size can be taken as an approximate measure of brain size, and the effects of nutrition on head size can be taken as effects on brain size. The effect of malnutrition on the brain of the fetus is to reduce the number of brain cells (Thatcher & Cantor, 1984). The head size of infants is positively associated with their DQs, e.g. at \( r = 0.36 \) (age = 14 months, \( n = 120 \) (Majluf, 1983) and the brain size of adults is correlated with intelligence at approximately 0.40 (Vernon, Wickett, Bazana, & Stelmack, 2000).

5. Positive correlations between DQs and IQs

The theory that pre-natal and early post-natal nutrition have been responsible for the secular increases that have taken place in DQs of infants, the IQs of preschool children, and the IQs of older children and adults implies that there should be a positive correlation between these three measures. The reason for this is that differences in nutrition should affect all these measures and bring them into positive correlation. In an early study of whether this is so, Honzik, MacFarlane and Allen (1948) reported that mental tests at the age of 2–3 years are correlated at .33 with IQs in adulthood. In another early study, Bayley (1949) concluded that DQs measured at the age of 12 months had no correlation \( (r = 0.14) \) with IQs in adulthood, but DQs measured at the age of 2–3 years are correlated at .40 with IQs in adulthood. The issue of whether infant DQs are positively related to later IQs was subsequently reviewed by Fagan and Singer (1983), who concluded that infant tests of sensory-motor development at ages 3–7 months have little predictive value for IQs at the age of 6+ years \( (r = .65) \), but at ages 8–11 months these tests predict IQs at the age of 6+ years at \( r = .21 \). This was confirmed by McCall and Carriger (1993) in a review of 27 studies that reported correlations of infant measures of habituation (37) and for preference for novelty (41) with later childhood IQs (there are measures of habituation and for preference for novelty in the Bayley DQ scales). Ten studies of the correlation of the DQs of infants with their subsequent IQs are summarized in Table 3. All the correlations are statistically significant. These correlations are not corrected for measurement error and range restriction, so these are underestimate of their true population values. Further evidence for a positive relationship between DQs and IQs has been provided by Smith, Flick, Ferriss, and Sellman (1972) and Rubin and Balow (1979).
who have reported that Bayley DQ at 8 months predicts IQ at age 6 and 7, and at age 4 and 7, respectively.

A recent study by Fagan, Holland, and Wheeler (2007) confirms the positive relationships between the development of infants, the IQs of preschool children, and the IQs of adults. They report that the development of infants aged 6–12 months (measured by attention to novelty) is significantly correlated at 0.34 with IQ at the age of 3 years, and at 0.26 (0.53 corrected for unreliability) with IQ at the age of 21 years, while IQ at the age of 3 years is correlated at 0.70 with IQ at the age of 21 years. In another recent study it has been shown that the development of infants aged 12 months (measured by attention to novelty and imitation) is significantly correlated at between 0.19 and 0.35 with Bayley Mental Development at the ages of 2 and 3 years (Rose, Feldman, Jankowski, & van Rosssem, 2008). Thus, numerous have confirmed that there are positive correlations between the DQs of infants, the IQs of preschool children, and the IQs of older children and adults.

### 6. Gains in fluid and crystallized intelligence

The nutrition theory of the Flynn effect explains why fluid intelligence has increased so much more than crystallized intelligence. Several studies have shown that sub-optimal nutrition impairs fluid intelligence more than crystallized intelligence (e.g. Lundgren et al., 2003), while nutritional supplements given to children raise their fluid IQs more than their crystallized IQs (Benton, 2001; Lynn & Harland, 1998; Schoenthaler, Bier, Young, Nichols, & Janssens, 2000). Hence as nutrition has improved over the course of the twentieth century, fluid intelligence has increased more than crystallized intelligence. It has even been shown that the Wechsler subtests (i.e. similarities and block design) that are most impaired by sub-optimal nutrition and improve most with nutritional supplements are those for which the Flynn effects have been the greatest (Botez, Botez, & Maag, 1984).

Flynn (2007) has attempted to refute the nutrition theory of the Flynn effect by asserting that there is no evidence that nutrition has improved in the second half of the twentieth century. Much contrary evidence has been summarized in Section 4 (above). Flynn (2007, p.105) asserts that there have been no increases in height in the United States in children born after about 1952, although intelligence has continued to increase, so IQ increases cannot be attributed to improvements in nutrition indexed by increases in height. Contrary to this contention, the data compiled by Komlos and Lauderdale (2007) show that height in the United States increased in those born from 1955 to 1975 (white men from 177.8 to 179.5; white women from 164.1 to 164.9), although height stabilised in the cohorts born after 1975. From 1975 until 2001 IQs appear to have continued to increase in the United States, although one data set comparing the WISC-III and the WAIS-III for the years 1989–1995 shows a decline (Flynn, 2007, p. 184). In Europe heights and intelligence increased from 1960 to 1990 (Larnkjær et al., 2006), while from around 1990–2000 heights and intelligence have both stabilized in Denmark, Norway and Britain (Teasdale and Owen, 2008; Sundet, Barlaug, & Torjussen, 2004; Shayer, 2007). The evidence shows broad consistency from around 1920 to the early twenty-first century in the parallel secular increases in height and intelligence. However, the nutrition theory of the secular increase of intelligence does not require perfect synchrony between increases in height and intelligence. There appear to be some micronutrients the lack of which does not adversely affect height but adversely affects the development of the brain and intelligence. Thus, although heights have stabilized in the United States and Europe in the closing decades of the twentieth century, nutrition was still not optimal in economically developed countries: “although children’s diets in developed societies adequately meet energy requirements, they are often sub-optimal in micronutrients” (Arija et al., 2006, p.147). For instance, in the United States a survey of 1987–88 found that in a representative sample of 2,379 9–10 year old girls 20% of blacks and 25% of whites had below the RDA (recommended daily allowance) of 45 mg a day of vitamin C (Simon, Schreiber, Crawford, Frederick, & Sabry, 1993). Vitamin C deficiency is one of the nutrients that has been shown to have an adverse effect on intelligence (Lynn & Harland, 1998). In Spain, nutritional deficiencies in iron and folate were found in around 50% of a sample of medium-high socio-status children and these deficiencies were significantly associated with lower IQs (Arija et al., 2006, p.146).

This may also explain the Nettleback and Wilson (2004) finding that vocabulary improved in Australian school children over the years 1981–2001, but inspection time has remained unchanged. The explanation may be that vocabulary is sensitive to an improvement in micronutrients that do not affect inspection time. However, the evidence on the Flynn effect in Australia is conflicting because Cotton et al. (2005) found no increase in the IQs of 6–11 year olds measured by the Colored Progressive Matrices over the period 1975–2003.

### 7. Progressive matrices gains

While IQs measured by the Wechsler and Binet tests have shown increases of approximately 3 IQ points a decade in the United States and a number of countries in Europe, there have been greater increases on Raven’s Progressive Matrices and similar non-verbal reasoning tests among 18 year old military conscripts and adults. Flynn (1987) gives results for seven studies in which the median rate of secular increase has been 6.7 IQ points per decade, more than double the rate of approximately 3 IQ points per decade obtained on the Wechsler and Binet tests.

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**Table 3**

<table>
<thead>
<tr>
<th>N</th>
<th>DQ test</th>
<th>Age (weeks)</th>
<th>IQ test</th>
<th>Age (years)</th>
<th>R</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>23,919</td>
<td>Bayley P</td>
<td>34</td>
<td>S.Binet</td>
<td>4</td>
<td>.23</td>
<td>Broman et al., 1975</td>
</tr>
<tr>
<td>25,017</td>
<td>Bayley P</td>
<td>34</td>
<td>S.Binet</td>
<td>4</td>
<td>.22</td>
<td>&quot;</td>
</tr>
<tr>
<td>596</td>
<td>Gesell</td>
<td>40</td>
<td>S.Binet</td>
<td>3</td>
<td>.48</td>
<td>Knobloch and Pasamanick, 1960</td>
</tr>
<tr>
<td>213</td>
<td>Gesell</td>
<td>26</td>
<td>S.Binet</td>
<td>3</td>
<td>.15</td>
<td>Capute, Shapiro, Palmer, Ross, &amp; Wachel, 1985</td>
</tr>
<tr>
<td>596</td>
<td>Gesell</td>
<td>26</td>
<td>S.Binet</td>
<td>5</td>
<td>.54</td>
<td>Drillien, 1961</td>
</tr>
<tr>
<td>219</td>
<td>Griffiths</td>
<td>52</td>
<td>WPPSI</td>
<td>7</td>
<td>.25</td>
<td>Largo, Graf, Kundu, Hunziker, &amp; Molinari, 1990</td>
</tr>
</tbody>
</table>

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(Section 4 (above). Flynn (2007, p.105) asserts that there have been no increases in height in the United States in children born after about 1952, although intelligence has continued to increase, so IQ increases cannot be attributed to improvements in nutrition indexed by increases in height. Contrary to this contention, the data compiled by Komlos and Lauderdale (2007) show that height in the United States increased in those born from 1955 to 1975 (white men from 177.8 to 179.5; white women from 164.1 to 164.9), although height stabilised in the cohorts born after 1975. From 1975 until 2001 IQs appear to have continued to increase in the United States, although one data set comparing the WISC-III and the WAIS-III for the years 1989–1995 shows a decline (Flynn, 2007, p. 184). In Europe heights and intelligence increased from 1960 to 1990 (Larnkjær et al., 2006), while from around 1990–2000 heights and intelligence have both stabilized in Denmark, Norway and Britain (Teasdale and Owen, 2008; Sundet, Barlaug, & Torjussen, 2004; Shayer, 2007). The evidence shows broad consistency from around 1920 to the early twenty-first century in the parallel secular increases in height and intelligence. However, the nutrition theory of the secular increase of intelligence does not require perfect synchrony between increases in height and intelligence. There appear to be some micronutrients the lack of which does not adversely affect height but adversely affects the development of the brain and intelligence. Thus, although heights have stabilized in the United States and Europe in the closing decades of the twentieth century, nutrition was still not optimal in economically developed countries: “although children’s diets in developed societies adequately meet energy requirements, they are often sub-optimal in micronutrients” (Arija et al., 2006, p.147). For instance, in the United States a survey of 1987–88 found that in a representative sample of 2,379 9–10 year old girls 20% of blacks and 25% of whites had below the RDA (recommended daily allowance) of 45 mg a day of vitamin C (Simon, Schreiber, Crawford, Frederick, & Sabry, 1993). Vitamin C deficiency is one of the nutrients that has been shown to have an adverse effect on intelligence (Lynn & Harland, 1998). In Spain, nutritional deficiencies in iron and folate were found in around 50% of a sample of medium-high socio-status children and these deficiencies were significantly associated with lower IQs (Arija et al., 2006, p.146).

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Part of the explanation of these large gains is that the Progressive Matrices measures fluid intelligence and this has increased more than crystallized intelligence. A further likely factor proposed by Blair et al. (2005) is that more recent cohorts have had more education in math. The positive effect of additional education on performance on the Progressive Matrices has been demonstrated by Cahan & Cohen (1989). The Progressive Matrices are largely mathematical problem solving tests, as shown by Carpenter, Just, and Shell (1990) in their analysis of the cognitive skills required to solve the items, which consist of the application of five mathematical rules involving addition, subtraction and arithmetic and geometrical progression. During the twentieth century adolescents received progressively more schooling during which they acquired these mathematical skills and which they have been able to apply to the solution of matrices problems. This explanation is supported by two studies. First, among school age children gains on the Progressive Matrices were only 2 IQ points a decade from 1938 to 1979 (Lynn & Hampson, 1986). Second, Colom, Andres-Pueyo, & Juan-Espinosa (1998) have shown that the IQ gain in military conscripts in Spain from the 1960s to the 1990s has been 6.86 IQ points per decade, virtually identical to the gains for other military conscript samples reported by Flynn (1987). However, among 18 year old applicants for university places over the same period the rate of gain has been only 2.41 IQ points per decade. The difference between the two figures is explained by the fact that the university applicants 1960s and the 1990s had the same amount of education and therefore showed about the same rate of gain as that obtained on the Wechsler and Binet samples reported by Flynn (2007). The military conscripts in the later year had had more education and consequently obtained a larger gain.

8. Conclusion

Those who have proposed that the Flynn effect has been caused by improvements in education, greater test sophistication, more cognitively stimulating environments, the “individual multiplier” and the “social multiplier”, etc. have apparently not noted there has been a secular increase in the DQs of infants aged 6–24 months, and in the IQs of preschool children. The most straightforward explanation for the similar rates of increase of DQs, the IQs of preschool children and IQs of school students is that the same factor has led to all these increases. Putting together all the strands of evidence summarized in this paper, it is proposed that this factor has been the improvements in pre-natal and early post-natal nutrition during the twentieth century that have been responsible for increases in infant birth weight, head size and brain size, increases in the DQs of infants between the ages of 6 months and two years, increases in height, and increases of similar magnitude in Wechsler and Binet IQs of preschool children, school age students and adults. Military conscripts have shown larger IQ gains because these have been obtained on tests of fluid intelligence, which has improved more than crystallized intelligence, and because more recent cohorts have had more education in math.

References


