Intelligence 37 (2009) 16–24

Contents lists available at ScienceDirect

Intelligence

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

Richard Lynn

University of Ulster, Coleraine, Northern Ireland, BT52 1SA, UK

ARTICLE INFO

Article history:
Received 23 March 2008
Received in revised form 17 July 2008
Accepted 17 July 2008
Available online 21 September 2008

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

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.

Contents

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,

E-mail address: Lynnr540@aol.com.

0160-2896/$ – see front matter
doi:10.1016/j.intell.2008.07.008

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), Flieller (1996, 1999, p.1056), Greenfield (1998), Garlick (2002) and Blair, Gamson, Thorne, and Baker (2005).

(2) Increased 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 wiseness 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". Flieller (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 that 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 Broman, 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.

Table 1
Secular gains on the Bayley scales of infant development in the United States and Australia

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

Table 2
Secular gains on the Griffiths Test in Britain, 1949–1980 (Hanson et al., 1985)

Scale	*N*	Age (months)	Gain	Gain per decade
Motor	326	6	10.7	3.5
Personal–social	326	6	12.9	4.2
Hearing–speech	326	6	7.7	2.5
Eye–hand	326	6	5.8	1.9
Performance	326	6	5.8	1.9
Motor	121	18	10.8	3.5
Personal–social	121	18	5.7	1.8
Hearing–speech	121	18	2.7	0.9
Eye–hand	121	18	6.7	2.2
Performance	121	18	7.1	2.3

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

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 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.

(2) 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 & Ohsawa, 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).

(3) The quality of pre-natal nutrition is a determinant of the birth weight of infants (Naeye, 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, &

Delgado, 1976; McDonald et al., 1981; Cameron, 1991; Mardones-Santander et al., 1991). Birth weight is positively associated with DQs in the first year of life. For instance, Brazelton, Tronik, Lechtig, Lasky, and Klein (1977) report a study of 157 infants among whom those with birth weights of 3500 g were advanced at 28 days by approximately 15 DQ points, as compared with those with birth weights below this figure. Drillien, 1969) reported a study of 423 infants in Scotland in which those with birth weights of less than 2000 g scored 12 DQ points lower than those with birth weights of 2500 and over at the ages of 6 months through 2 years. Numerous studies have found that birth weight is positively associated with IQs, e.g. Lundgren, Cnattingius, Jonsson, and Tuvemo (2003); and low birth weight reduces IQ by 5 IQ points up to the age of 17 (Breslau, Dickens, Flynn, Peterson, & Lucia (2006). The birth weight of infants is also highly correlated with their head size, e.g. at 0.75 in the Broman et al. (1975) study of 26,760 babies.

(4) The quality of pre-natal nutrition is a determinant of the head size of infants, of their DQs infancy and also their IQs in childhood, e.g. pregnant women in Guatemala given nutritional supplements had babies with greater birth weight, greater head size, higher DQs in the first and second years of life, and higher IQs at age 3 years (Klein et al., 1976). Nutritional supplements given to 198 pregnant women in Taiwan raised the DQs of their infants at 36 weeks by 5 DQ points on the Bayley Motor Scale (Joos, Pollitt, Mueller, & Albright, 1983).

(5) The quality of post-natal nutrition obtained by infants is also positively associated with their DQs. Numerous studies reviewed by Greisel (1984) have found that poorly nourished infants have low DQs. Nutritional supplements of iron given to anaemic infants raises their DQs (Oski & Honig, 1978; Walter, Kovalskys, & Stekel, 1983; Aukett, Parks, Scott & Wharton, 1986; Oski, Honig, Helu, & Howanitz, 1983).

A study of 47 infants who failed to grow during their first 15 months as a result of poor nutrition, producing low weight-for-age, scored 10 DQ points lower on the Bayley Mental Scale and 7 DQ points lower on the Bayley Motor Scale than a control group matched for sex, ethnicity, birthweight, birth order and socio-economic status failure (Skuse, Pickles, Wolke and Reilly, 1994). A study of 57 infants in Colombia given nutritional supplements in the last trimester of their mother's pregnancy and their first 12 months scored 13 DQ points higher at the age of 1 year than a matched control group of 44 controls who had received no supplements (Waber et al., 1981). A study of 153 toddlers in Egypt showed quality of nutrition between 18 and 23 months significantly correlated with Bayley mental development at 24 months (Wachs et al., 1993).

(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 (−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 ($r=.065$), 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 underestimates 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)

Table 3
Correlations between DQs of infants and subsequent IQs

N	DQ test	Age (weeks)	IQ test	Age (years)	*R*	Reference
23,919	Bayley P	34	S.Binet	4	.23	Broman et al., 1975
"	Bayley M	34	S.Binet	4	.22	"
25,017	Bayley P	34	S. Binet	4	.25	"
"	Bayley M	34	S.Binet	4	.24	"
626	Bayley P	32	WISC	7	.19	Goffeney et al., 1971
"	Bayley M	32	WISC	7	.17	"
300	Gesell	40	S.Binet	3	.48	Knobloch and Pasamanick, 1960
213	Gesell	26	S.Binet	3	.15	Capute, Shapiro, Palmer, Ross, & Wachel, 1985
596	Gesell	26	S.Binet	5	.54	Drillien, 1961
219	Griffiths	52	WPPSI	7	.25	Largo, Graf, Kundu, Hunziker, & Molinari, 1990

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; Schoenthaller, Bier, Young, Nichols, & Jansenns, 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-111 and the WAIS-111 for the years 1989–1995 shows a decline (Flynn, 2007, p. 184). In Europe heights and intelligence increased from 1960 to 1990 (Larnkjaer 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.

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 arithmetical 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

Alberman, E., Filakti, H., Williams, S., & Evans, S. J. (1991). Early influences on the secular change in adult height between the parents and children of the 1958 birth cohort. *Annals of Human Biology*, *18*, 127−136.

Arija, V., Esparo, G., Fernandez-Ballart, J., Murphy, M. M., Biarnes, E., & Canals, J. (2006). Nutritional status and performance in test of verbal and non-verbal intelligence in 6 year old children. *Intelligence*, *34*, 141−149.

Aukett, M. A., Parks, Y. A., Scott, P. H., & Wharton, B. A. (1986). Treatment with iron increases weight gain and psychomotor development. *Archives of Diseases of Childhood*, *61*, 849−857.

Barnett, S. M., & Williams, W. (2004). National intelligence and the emperor's new clothes: IQ and the Wealth of Nations. *Contemporary Psychology*, *49*, 389−396.

Bayley, N. (1933). *The California First-Year Mental Scale.* Berkeley: University of California Press.

Bayley, N. (1936). *The California First-Year Motor Scale.* Berkeley: University of California Press.

Bayley, N. (1949). Consistency and variability in the growth of intelligence from birth to eighteen years. *Journal of Genetic Psychology*, *75*, 165−196.

Bayley, N. (1965). *Bayley Scales of Infant Development.* San Antonio, TX: Psychological Corporation.

Bayley, N. (1993). *Bayley Scales of Infant Development.* San Antonio, TX: Psychological Corporation.

Benton, D. (2001). Micro-nutrient supplementation and the intelligence of children. *Neuroscience and Behavioral Reviews*, 297−309.

Black, M. M., Hess, C. R., & Berenson-Howard, J. (2000). Toddlers from low-income families have below normal mental, motor and behavior scores on the revised Bayley Scales. *Journal of Applied Developmental Psychology*, *21*, 655−666.

Blair, C., Gamson, D., Thorne, S., & Baker, D. (2005). Rising mean IQ: Cognitive demand of mathematics education for young children, population exposure to formal schooling, and the neurobiology of the prefrontal cortex. *Intelligence*, *33*, 93−106.

Board of Education (1931). *Report on the Health of British Children.* London: HMSO.

Bocerean, C., Fischer, J. -P., & Flieller, A. (2003). Long term comparison (1921–2001) of numerical knowledge in 3 to five and a half year old children. *European Journal of Psychology of Education*, *18*, 405−424.

Botez, M. I., Botez, T., & Maag, U. (1984). The Wechsler subtests in mind organic brain damage associated with folate deficiency. *Psychological Medicine*, *14*, 431−437.

Brand, C. R. (1987). Bryter still and bryter? *Nature*, *328*, 110.

Brand, C. R., Freshwater, S., & Dockrell, W. B. (1989). Has there been a massive rise in IQ levels in the West? Evidence from Scottish children. *Irish Journal of Psychology*, *10*, 388−393.

Brandt, I. (1978). Growth dynamics of low-birth weight infants with emphasis on the perinatal period. In F. Falkner, & J. M. Tanner (Eds.), *Human Growth*, *Vol. 2*. (pp. 557−617)New York: Plenum.

Brazelton, T. B., Tronik, E., Lechtig, A., Lasky, R. E., & Klein, R. E. (1977). The behavior of nutritionally deprived Guatemalan infants. *Developmental Medecine and Child Neurology*, *19*, 364−372.

Breslau, N., Dickens, W. T., Flynn, J., Peterson, E. L., & Lucia, V. C. (2006). Low birth weight and social disadvantage: Tracking their relationship with children's IQs during the period of school attendance. *Intelligence*, *34*, 351−362.

Broman, S. H., Nichols, P. L., & Kennedy, W. A. (1975). *Preschool IQ: Prenatal and Developmental Correlates.* Hillsale, NJ: Wiley.

Cahan, S., & Cohen, N. (1989). Age versus schooling effects on intelligence development. *Child Development*, *60*, 1239−1249.

Cameron, N. (1991). Human growth, nutrition and health status in sub-Saharan Africa. *Yearbook of Physical Anthropology*, *34*, 211−250.

Campbell, S. K., Siegel, E., Parr, C. A., & Ramey, C. T. (1986). Evidence for the need to renorm the Bayley Scales of Infant Development based on the performance of a population-based sample of 12 month old infants. *Topics in Early Childhood Education*, *6*, 83−96.

Capute, A. J., Shapiro, B. K., Palmer, F. B., Ross, A., & Wachel, R. C. (1985). Cognitive-motor interactions. *Clinical Pediatrics*, *24*, 671−675.

Carpenter, P. A., Just, M. A., & Shell, P. (1990). What one intelligence test measures: a theoretical account of the processes in the Raven Progressive Matrices Test. *Psychological Review*, *97*, 404−413.

Cattell, R. B. (1950). The fate of national intelligence: Test of a thirteen year prediction. *Eugenics Review*, *17*, 136−148.

Cernerud, L., (1993). Differences in height between socially more and less privileged 10 year old Stockholm children born in 1933–1963. Unpublished ms.

Chinn, S., & Rona, R. J. (1987). Secular trends in weight, weight for height and triceps skinfold thickness in primary school children in England and Scotland from 1972 to 1980. *Annals of Human Biology*, *14*, 311−319.

Cole, T. J. (1994). Growth charts for both cross-sectional and longitudinal data. *Statistics in Medicine*, *13*, 2477−2492.

Colom, R., Andres-Pueyo, A., & Juan-Espinosa, M. (1998). Generational gains: Spanish data. *Personality and Individual Differences*, *25*, 927−935.

Colom, R., Lluis-Font, J. M., & Andres-Pueyo, A. (2005). The generational intelligence gains are caused by decreasing variance in the lower half of the distribution: Supporting evidence for the nutrition hypothesis. *Intelligence*, *33*, 83−92.

Cotton, S. M., Kiely, P. M., Crewther, D. P., Thomson, B., Laycock, R., & Crewther, S. G. (2005). A normative and reliability study for the Raven's Colored Progressive Matrices for primary school aged children in Australia. *Personality and Individual Differences*, *39*, 647−660.

Darke, S. J., Disselduff, M. M., & Try, G. P. (1980). Frequency distributions of mean daily intakes of food energy and selected nutrients obtained during nutrition surveys of different groups of people in Great Britain between 1968 and 1971. *British Journal of Nutrition*, *44*, 243−252.

Dickens, W. T., & Flynn, J. R. (2001). Heritability estimates versus large environmental effects: the IQ paradox resolved. *Psychological Review*, *108*, 346−369.

Drillien, C. M. (1961). Longitudinal study of growth and development of prematurely and maturely born children: V11: Mental development 2–5 years. *Archives of Diseases in Childhood*, *36*, 233−240.

Drillien, C. M. (1969). School disposal and performance for children of different birthweight born 1953–1960. *Archives of Diseases in Childhood*, *44*, 562−570.

Dunn, J. T. (1994). Societal implications of iodine deficiency and the value of its prevention. In J. B. Stanbury (Ed.), *The Damaged Brain of Iodine Deficiency* New York: Cognizant Communication Corporation.

Elley, W. B. (1969). Changes in mental ability in New Zealand. *New Zealand Journal of Educational Studies*, *4*, 140−155.

Fagan, J. F., Holland, C. R., & Wheeler, K. (2007). The prediction from infancy of adult IQ and achievement. *Intelligence*, *35*, 22−231.

Fagan, J. F., & Singer, L. T. (1983). Infant recognition memory as a measure of intelligence. In L. P. Lipsett (Ed.), *Advances in Infancy Research*, *Vol. 2*. (pp.) Norwood, NJ: Ablex.

Flieller, A. (1996). Trends in child rearing practices as a partial explanation for the increase in children's scores on intelligence and cognitive development tests. *Polish Quarterly of Developmental Psychology*, *2*, 51−61.

Flieller, A. (1999). Comparison of the development of formal thought in adolescent cohorts aged 10–15 years (1967–1996 and 1972–1993). *Developmental Psychology*, *35*, 1048−1058.

Flynn, J. R. (1984). The mean IQ of Americans: Massive gains 1932 to 1978. *Psychological Bulletin*, *95*, 29−51.

Flynn, J. R. (1987). Massive IQ gains in 14 nations: What IQ tests really measure. *Psychological Bulletin*, *101*, 171−191.

Flynn, J. R. (2007). *What is Intelligence? Beyond the Flynn effect.* Cambridge: Cambridge University Press.

Garlick, D. (2002). Understanding the nature of the general factor of intelligence: The role of individual differences in neural plasticity as an exploratory mechanism. *Psychological Review*, *109*, 116−136.

Goffeney, B., Henderson, N. B., & Butler, B. V. (1971). Negro-white, male-female eight-month development scores compared with seven year WISC and Bender Test scores. *Child Development*, *42*, 595−604.

Greenfield, P. M. (1998). The cultural evolution of IQ. In U. Neisser (Ed.), *The Rising Curve* Washington, DC: American Psychological Association.

Griesel, R. D. (1984). Psychomotor development of malnourished African children. In J. Brozek, & B. Schurch (Eds.), *Malnutrition and Behavior: Critical Assessment of Key Issues* Lausanne, Switzerland: Nestle Foundation.

Griffiths, R. (1954). *The Abilities of Babies.* High Wycombe, UK: Test Agency.

Honzik, M. P., MacFarlane, J. W., & Allen, L. (1948). Stability of mental performance between 2 and 18 years. *Journal of Experimental Education*, *17*, 309−324.

Hanson, R., Smith, J. A., & Hume, W. (1985). Achievements of infants on items of the Griffiths scales: 1980 compared with 1950. *Child: Care, Health and Development*, *11*, 91−104.

Jensen, A. R. (1998). *The g Factor.* Westport,CT: Praeger.

Ji, C. C., & Ohsawa (1993). Growth changes of Chinese Mongolian, Uygur, Korean, and Tibetan ethnic groups in the past forty years. *American Journal of Human Biology*, *5*, 311−322.

Joos, S. K., Pollitt, E., Mueller, W. H., & Albright, D. L. (1983). The Bacon Chow study: maternal nutrition supplementation and infant behavioural development. *Child Development*, *54*, 669−676.

Klein, R. E., Arenales, P., & Delgado, H. (1976). Effects of maternal nutrition on fetal growth and infant development. *Bulletin of the Pan-American Health Organisation*, *10*, 301−316.

Knobloch, H., & Pasamanick, B. (1960). An evaluation of the consistency and predictive value of the 40 week Gesell developmental schedule. *Psychiatric Research Reports of the American Psychiatric Association*, *13*, 10−13.

Komlos, J., & Lauderdale, B. E. (2007). The mysterious trend in American heights in the 20 century. *Annals of Human Biology*, *34*, 206−215.

Kretschmann, H. T., Schleicher, A., Wingert, F., Zilles, K., & Loblich, H. J. (1979). Human brain growth in the 19th and 20th century. *Journal of the Neurological Sciences*, *40*, 169−188.

Largo, R. H., Graf, S., Kundu, S., Hunziker, U., & Molinari, L. (1990). Predicting developmental outcome at school age from infant tests of normal, at-risk and retarded infants. *Developmental Medicine and Child Neurology*, *32*, 30−45.

Larnkjaer, A., Schroder, S. A., Schmidt, I. M., Jorgensen, M. H., & Michaelsen, K. F. (2006). Secular change in adult stature has come to a halt in northern Europe and Italy. *Acta Paediatrica*, *95*, 754−755.

Lucas, A., Morley, R., & Cole, T. J. (1998). Randomised trial of early diet in preterm babies and later intelligence quotient. *British Medical Journal*, *317*, 1481−1487.

Lundgren, E. M., Cnattingius, S., Jonsson, B., & Tuvemo, T. (2003). Birth characteristics and different dimensions of intellectual performance in young males: a nationwide population-based study. *Acta Paediatrica*, *92*, 1138−1143.

Lynn, R. (1990). The role of nutrition in secular increases of intelligence. *Personality and Individual Differences*, *11*, 273−285.

Lynn, R. (1993). Nutrition and intelligence. In P. A. Vernon (Ed.), *Biological Approaches to the Study of Intelligence* Norwood, NJ: Ablex.

Lynn, R. (1998). In support of nutrition theory. In U. Neisser (Ed.), *The Rising Curve* Washington, DC: American Psychological Association.

Lynn, R., & Hampson, S. L. (1986). The rise of national intelligence: Evidence from Britain, Japan and the USA. *Personality and Individual Differences*, *7*, 23−332.

Lynn, R., & Harland, E. P. (1998). A positive effect of iron supplementation on the IQs of iron deficient children. *Personality and Individual Differences*, *24*, 883−887.

Majluf, A. (1983). Desarrolo mental, postutal y somatico de infants de 8, 14 y meses de edad, de clase socio-economica media y baja de Lima. *Revista Latinoamericana de Psychologia*, *15*, 369−386.

Mardones-Santander, F., Rosso, P., Zamora, R., Mardones-Restat, F., Gonzales, N., & Uiterwaaal, D. (1991). Cost-effectiveness of a nutrition intervention program for pregnant women. *Nutrition Research*, *11*, 295−307.

McCall, R. B., & Carriger, M. (1993). A meta-analysis of infant habituation and recognition memory performance as predictors of later IQ. *Child Development*, *64*, 57−79.

McDonald, E. C., Pollitt, E., Mueller, W., Hsueh, A. M., & Sherwin, R. (1981). The Bacon Chow study: Maternal nutrition supplementation and birth weight of offspring. *American Journal of Clinical Nutrition*, *34*, 2133−2144.

Meisenberg, G., Lawless, E., Lambert, E., & Newton, A. (2006). Determinants of mental ability on a Caribbean island and the mystery of the Flynn effect. *Mankind Quarterly*, *46*, 273−312.

Mingroni, M. A. (2004). The secular rise in IQ: Giving heterosis a closer look. *Intelligence*, *32*, 65−83.

Mingroni, M. A. (2007). Resolving the IQ paradox: Heterosis as a cause of the Flynn effect and other trends. *Psychological Review*, *114*, 1104.

Naeye, R. L., Diener, M. M., & Dellinger, W. S. (1969). rban poverty: Effects on prenatal nutrition. *Science*, *166*, 1026−1028.

Nagoshi, C. T., & Johnson, R. C. (1987). Between- versus within-family factor analyses of cognitive abilities. *Intelligence*, *11*, 305−316.

Nettleback, T., & Wilson, C. (2004). The Flynn effect: Smarter not faster. *Intelligence*, *32*, 85−93.

Oski, F. A., & Honig, A. S. (1978). The effects of therapy on the developmental scores of iron-deficient infants. *Journal of Pediatrics*, *92*, 21−25.

Oski, F. A., Honig, A. S., Helu, B., & Howanitz, P. (1983). Effect of iron therapy on behavior performance in non-anemic, iron deficient infants. *Pediatrics*, *71*, 877−880.

Orr, J. B. (1936). *Food, health and income.* London: Macmillan.

Ounsted, M., Moar, V. A., & Scott, A. (1985). Head circumference charts updated. *Archives of Diseases of Childhood*, *60*, 936−939.

Palmer, C. E. (1935). Height and weight of children of the depressed poor. *Public Health Reports*, *59*, 33−35.

Persson, L. A., Samuelson, G., & Sjolin, S. (1989). Nutrition and health in Swedish children 1930–1980. *Acta Pediatrica Scandinavia*, *78*, 865−872.

Rabbitt, P. (2006). Tales of the unexpected. *The Psychologist*, *19*, 674−676.

Roede, M. J., & Van Wieringen, J. C. (1985). Growth diagrams 1980. *Tijdschrift Poor Sociale Gezondheidszorg*, *63*, 1−34.

Rooth, G. (2003). Increase in birthweight: A unique biological event and an obstretrical problem. *European Journal of Obstretrics & Gynecology and Reproductive Biology*, *106*, 86−87.

Rose, S. A., Feldman, J. F., Jankowski, J. J., & van Rosssem, R. (2008). A cognitive cascade in infancy: Pathways from prematurity to later mental development. *Intelligence*, *36*, 367−378.

Rubin, R., & Balow, B. (1979). Measures of infant development and socio-economic status as predictors of later intelligence and school achievement. *Developmental Psychology*, *15*, 225−227.

Schoenthaller, S. J., Bier, I. D., Young, K., Nichols, D., & Jansenns, S. (2000). The effect of vitamin–mineral supplementation on the intelligence of American school children: A randomised, double-blind placebo-controlled trial. *Journal of Alternative and Complementary Medicine*, *6*, 19−29.

Schooler, C. (1998). Environmental complexity and the Flynn effect. In U. Neisser (Ed.), *The Rising Curve* Washington, DC: American Psychological Association.

Scottish Council for Research in Education (1949). *The Trend of Scottish Intelligence.* London: University of London Press.

Shayer, M. (2007). 30 years on—a large anti-'Flynn effect'? The Piagetian test volume & heaviness norms 1975–2003. *British Journal of Educational Psychology*, *77*, 25−42.

Simon, J. A., Schreiber, G. B., Crawford, P. B., Frederick, M. M., & Sabry, Z. I. (1993). Income and racial patterns of dietary vitamin C intake among black and white girls. *Public Health Reports*, *108*, 760−764.
Skuse, D., Pickles, A., Wolke, D., & Reilly, S. (1994). Postnatal growth and mental development: Evidence for a sensitive period. *Journal of Child Psychiatry*, *35*, 521−545.
Smith, A., Flick, G., Ferriss, G., & Sellman, A. (1972). Prediction of developmental outcome at seven years from prenatal, perinatal and postnatal events. *Child Development*, *43*, 495,507.
Stanbury, J. B. (1994). *The Damaged Brain of Iodine Deficiency.* New York: Cognizant Communication Corporation.
Sundet, J. M., Barlaug, D. G., & Torjussen, T. M. (2004). The end of the Flynn effect? A study of secular trends in mean intelligence test scores of Norwegian conscripts during half a century. *Intelligence*, *32*, 349−362.
Tasbihsazan, R., Nettlebeck, T., & Kirby, N. (1997). Increasing mental development Index in Australian children: A comparative study of two versions of the Bayley Mental Scale. *Australian Psychologist*, *32*, 120−125.
Teasdale, T. W., & Owen, D. R. (1994). Thirty year secular trend in the cognitive abilities of Danish male school leavers at a high educational level. *Scandinavian Journal of Psychology*, *35*, 328−335.
Teasdale, T. W., & Owen, L. (2008). Secular declines in cognitive test scores: A reversal of the Flynn effect. *Intelligence*, *36*, 121−126.
Thatcher, R. W., & Cantor, D. S. (1984). Electrophysiological techniques in the assessment of malnutrition. In J. Brozek, & B. Schurch (Eds.), *Malnutrition and Behavior: Critical Assessment of Key Issues* Lausanne, Switzerland: Nestle Foundation.
Tsuzaki, S., Matsuo, N., Ogata, T., & Osano, M. (1989). Lack of linkage between height and weight and age at menarche during the secular shift in growth of Japanese children. *Annals of Human Biology*, *16*, 429−436.
Tuddenham, R. D. (1948). Soldier intelligence in world wars 1 and 11. *American Psychologist*, *3*, 54−56.
Van Wieringen, J. C. (1978). Secular growth change. In F. Falkner, & J. M. Tanner (Eds.), *Human Growth*, *Vol. 2*. (pp. 445−474)New York: Plenum.
Vernon, P. A., Wickett, J. C., Bazana, P. G., & Stelmack, R. M. (2000). The neuropsychology and neurophysiology of human intelligence. In R. J. Sternberg (Ed.), *Handbook of Intelligence* Cambridge, UK: Cambridge University Press.
Waber, D. P., Vuori, L., Ortiz, N., Clement, J. R., Christiansen, N. E., Mora, J. O., Reed, R. B., & Herrera, M. G. (1981). Nutritional supplementation, maternal education, and cognitive development of infants at risk of malnutrition. *American Journal of Clinical Nutrition*, *34*, 807−813.
Wachs, T. D., Moussa, W., Bishry, Z., Yunis, F., Sobhy, A., McCabe, G., Jerome, N., Galan, O., Harrison, G., & Kirksley, A. (1993). Relations between nutrition and cognitive performance in Egyptian toddlers. *Intelligence*, *17*, 151−172.
Walter, T., Kovalskys, J., & Stekel, A. (1983). Effects of mild iron deficiency on infant mental development scores. *Journal of Pediatrics*, *102*, 519−522.
Weede, E., & Kampf, S. (2002). The impact of intelligence and institutional improvements on economic growth. *Kyklos*, *55*, 361−380.
Whitehead, R. G., & Paul, A. A. (1988). Comparative infant nutrition in man and other animals. In R. G. Whitehead, & A. A. Paul (Eds.), *Proceedings of the International Symposium on Comparative Nutrition* London: Libbey.
Wolf, A. (June 10 2005). People are getting cleverer. *Times Higher Educational Supplement*.