Person. individ. Diff. Vol. 11, No. 3, pp. 273–285, 1990
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0191-8869/90 $3.00 + 0.00

THE ROLE OF NUTRITION IN SECULAR INCREASES IN INTELLIGENCE

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(Received 16 June 1989)

Summary—In a number of economically developed nations the intelligence of the population has increased by approx. 1 standard deviation (SD) over the last half century. No satisfactory explanation for this increase has yet been forthcoming. In this paper it is argued that the major causal factor is improvements in nutrition. These have led to parallel increases in height, head circumference and brain size, and to improved neurological development and functioning of the brain. These are responsible for higher intelligence. Nutrition is still suboptimal for substantial proportions of the population and further increases in intelligence can be anticipated if standards of nutrition could be improved.

In the early years of the century it was widely believed that the intelligence of the populations in the economically advanced countries was declining as a result of the greater fertility of the less intelligent (Fisher, 1930; Cattell, 1937). In the last dozen years or so a series of studies in a number of different countries has shown that, on the contrary, mean IQs have been increasing over the last half century. These increases have been reported for the United States (Flynn, 1984a), Japan (Lynn, 1982; Lynn & Hampson, 1986), Britain (Lynn & Hampson, 1986; Lynn, Hampson & Mullineux, 1987; Lynn, Hampson & Howden, 1988; Lynn & Hampson, 1989) and for Australia, New Zealand and a number of countries of Continental Europe (Flynn, 1987). The size of the IQ gains varies somewhat with the tests used: tests of visuo-spatial abilities tend to show greater rates of increase than those of verbal-educational abilities (Lynn & Hampson, 1986; Flynn, 1987). There are also some variations from country to country, possibly due to the differences in samples, time periods and tests. Nevertheless, taking the evidence as a whole, the IQ gains have been broadly of the order of 3 IQ points per decade or 1 SD over the last half century.

These large secular increases in intelligence have proved puzzling to workers in this field and no explanation for them has been forthcoming. One leading investigator has argued that the increases cannot be genuine and therefore that intelligence tests do not measure intelligence (Flynn, 1987). This view is not accepted. It is proposed, rather, that the increases are genuine and that the cause of them lies in improvements in nutrition. This is the thesis that it is the objective of the present paper to establish.

SECULAR INCREASES IN HEIGHT

The first clue to the role of nutrition in the secular increases in intelligence lies in the parallel increases which have taken place in height. Increases in height over the last half century have been documented for virtually all the economically developed nations of Europe, North America and Japan. The rate of increase for young adults has been around 1.2 cm per decade (Van Wieringen, 1978; Roede & Van Wieringen, 1985). The SD for height is approx. 7 cm. Thus the secular increase in height over the last half century amounts to around 1 SD, about the same as the secular increases that have taken place in intelligence.

It is generally considered that the secular increases that have occurred in height are due to improvements in nutrition. A subsidiary factor may have been the reduction of infectious diseases. These can have debilitating effects and impair the utilisation of nutrients so that the reduction of infectious diseases can be subsumed under nutritional improvement.

There is no doubt that in the 1920s and 1930s nutrition was seriously suboptimal for large numbers of people in the economically developed nations. In Britain a Board of Education (1931) survey found that 87.5% of British children had signs of rickets, a symptom of vitamin D deficiency. In a study of the diet of the general population Orr (1936) concluded that at least half of the population in Britain were receiving inadequate vitamins and minerals and only 10% were obtaining adequate intakes of calcium. Corry Mann (1926) reported extensive nutritional deficiencies among adolescents and found that by giving them additional milk over the course of 6 months–1 yr there were improvements in growth rates and health. Similar conclusions regarding the widespread prevalence of suboptimal nutrition in the interwar period were reported in the United States and Japan (Palmer, 1935; Takahashi, 1966).

During the last half century there have been considerable improvements in living standards in the economically developed nations. These have allowed the populations to buy more foods and this has been the principal factor in the improvements in nutrition and consequent increases in height. The improvements in nutrition are particularly well documented in Japan through a series of post World War II national nutrition surveys. These have shown that from 1960 to 1980 there were substantial *per capita* increases in the consumption of meat, milk and dairy products (300%), fruit (100%), vegetables (50%) and fish (20%) (Takahashi, 1986).

Although height and IQ have both increased over the last half century, it does not of course necessarily follow that the parallel increases are due to the same cause. Nevertheless, if the increases in intelligence have also been due to the improvements in nutrition, i.e. if there is a common cause, we should expect to find positive correlations across individuals between height and IQ. There are numerous studies confirming that this is the case.

As early as 1893 the association was reported for 33,500 students by Porter (1893) using academic performance as a proxy for IQ. Among the largest studies, the Scottish 1947 survey of approx. 75,000 11 yr olds found a correlation between height and IQ of +0.25 (Scottish Council, 1953). A British study of 5362 children born in the first week of March 1948 found a correlation of +0.13 (Douglas, Ross & Simpson, 1965), and an American study of 13,887 youths in the 1960s reported a correlation of +0.19 (Wilson, Hammer, Duncan, Dornbusch, Ritter, Hintz, Gross & Rosenfeld, 1986). There have been many smaller scale studies reporting similar positive correlations. Since the most important environmental determinant of height is nutrition, the most straightforward explanation for the positive association between height and IQ is that both are functions of variance in nutrition.

NUTRITION AND THE BRAIN

The improvements in nutrition which have been responsible for the increases in height over the last half century have also led to increases in the size of the brain and probably in addition to improvements in the brain's neurological development and functional efficiency. The easiest secular improvement to observe is that of brain size, which is highly correlated at a magnitude of approx. 0.8 with the external circumference of the head and with other measures of head size such as the cephalic index (Brandt, 1978).

It has been shown in a number of studies that during the last half century there have been increases in head size and consequently of brain size. These increases have taken place from birth onwards. Among British 1 yr olds, average head circumference has increased by approx. 1.5 cm and among 7 yr olds by approx. 2.0 cm over the last 50 yr (Ounsted, Moar & Scott, 1985; Whitehead & Paul, 1988). In Hong Kong head circumference among 7–18 yr olds has increased by approx. 1 cm over the years 1965–1985 (Davies, Leung & Lau, 1985). Similar increases have been found in Japan (Morita & Ohtsuki, 1973). These increases are of the order of 1 SD over a half century, approximately the same that has occurred for height and IQ.

The secular increases that have taken place in head size reflect increases in brain size. There is in addition some direct evidence that brain size has been increasing from the study by Miller and Corsellis (1977) of the brain weights of some 7000 20–50 yr olds autopsied at the London Hospital over the period 1860–1940. They found that the fresh brain weights of men increased by approx. 6 g per decade over the 80 yr period. Similar results have been reported in Denmark and Germany (Pakkenberg & Voight, 1964; Roessle & Roulet, 1932).

There is little doubt that the increases that have occurred in head size and brain size over the last half century are due to the improvements that have taken place in nutrition. A number of studies have shown that poor nutrition reduces head size and brain size. Autopsy studies reporting

Table 1. Summary of studies on correlations between head size and intelligence

Ss	N	Test	Head measure	Correlation	Author
British children	4500	Teacher's ratings	Circumference	0.11	Pearson, 1906
British graduates	1000	Degree results	Circumference	0.10	Pearson, 1906
Bavarian soldiers	935	Ratings	Circumference	0.14	Pearl, 1906
French farmers	326	Progressive matrices	Circumference	0.23	Schreider, 1968
Belgian conscripts	2071	Progressive matrices	Circumference	0.13	Susanne & Sporoq, 1973
American boys	334	WISC	Circumference	0.35	Weinberg *et al.*, 1974
American children	26,760	Stanford–Binet	Circumference	0.14	Broman *et al.*, 1975
British children	310	PMA	Circumference	0.18	Lynn, 1989
American children	600	Otis, Terman	Diameter	0.22	Murdock and Sullivan, 1923
British adults	415	WAIS	Cranial capacity	0.14	Passingham, 1979
Polish students	302	Baley	Cranial capacity	0.14	Henneberg *et al.*, 1985

small brain size in malnourished children have been reported in Chile, Jamaica, Uganda, India and the United States (Winick, Rosso & Waterlow, 1970; Brown, 1966; Naeye, Diener & Dellinger, 1969; Parekh, Pherwani, Udani & Mukherjee, 1970).

The increases that have taken place in head size are one of the factors in the increases in intelligence. Larger heads contain larger brains, and larger brains have meant higher intelligence. There have been 11 studies of the relation between head size and intelligence and all of them have found a statistically significant positive association. The data from these studies are summarized in Table 1. Although many of the studies are quite antiquated, we have found in a study in Northern Ireland that positive correlations between head size and IQ are still present in the late 1980s and lie between 0.05 and 0.28 for different tests, giving an average of 0.18 (Lynn, 1989). Some investigators such as Pearson have partialled out various measures of body size and found that the correlation between head size and IQ remains statistically significant. In our own study we have used weight as the most convenient measure for body size and found no correlation between weight and IQ. We have found height correlated with both IQ and head size. The correlation between IQ and head size with height partialled out is reduced but not removed entirely. But we prefer not to consider height as a cause of head size or IQ and to attribute the positive correlations of height with head size and IQ to the common effect of nutrition.

Although the correlations between head size and intelligence are consistently positive they are quite low and average out at around 0.2. The true correlation between brain size and intelligence will be somewhat higher than this because head size is not a perfectly reliable measure of brain size, nor are intelligence tests (still less teachers' estimates) wholly reliable measures of intelligence. Van Valen (1974) has pointed out the imperfect reliability of the measures and suggests a true correlation between brain size and intelligence of approx. 0.3.

The positive association between head size and intelligence is corroborated by other types of evidence. First, several studies have found that the mentally retarded tend to have small heads (Book, Schut & Reed, 1953; Mosier, Grossman & Dingman, 1965). Second, it has been found that babies with low birth weights tend to have small heads later in life and low IQs. In Scotland a sample of 135 low birth weight babies (< 2500 g) were matched to a control group of normal weight and were found to have lower IQs by an average of 4.5 IQ points at the age of 10 yr (Illsley & Mitchell, 1984). In the United States it has been found that among low birth weight infants head circumference at age 8 months significantly predicts IQ at the age of 3 yr (Hack & Breslau, 1986).

The positive correlation between head size and intelligence is consistent with comparative data across species showing that species with larger brains perform better on a variety of cognitive tasks such as discrimination learning (Jerison, 1982; Mackintosh, Wilson & Boakes, 1985). Nevertheless, it could be argued that the positive correlation of head size and IQ in man is not causal but results from nutrition acting on both variables. The causal effect of nutrition on intelligence could operate through the neural development of the brain and could additionally affect head size and height, without head size as such being causal to IQ.

It is probable that nutrition does act in this way in addition to any causal effect it may have on intelligence via brain size. Studies on animals have shown that suboptimal nutrition of the foetus and in early life has adverse effects on the growth of the number of glial brain cells, the myelination of the neurones, the growth of dendrites and the formation of synaptic connections (Dobbing, 1984). There is evidence from autopsy studies that malnourishment has similar adverse effects in children (Winick *et al.*, 1970).

NUTRITION AND INTELLIGENCE

We consider now the evidence for a direct link from nutrition to intelligence. A number of studies have shown that infants experiencing poor nutrition tend to have low intelligence in later childhood and adolescence. However, many of these are not convincing evidence for a casual association because of the presence of a number of other confounding conditions. Malnourished children are generally brought up by parents who are themselves of low intelligence in familes which provide poor conditions for cognitive development in a number of respects among which poor nutrition is only one. These studies normally include control groups matched for socio-economic status to the malnourished group, but it is difficult in designs of this kind to provide control families which adequately match the families with malnourished children.

The most convincing studies of a casual effect of malnutrition on intelligence are derived from identical (mz) twins born with different birth weights. Such differences are generally attributed to reduced blood flow from the placenta to one twin leading to a reduced supply of nutrients, retarded growth and small size at birth. Since the twin pairs are genetically identical and experience the same family environment the only difference between them lies in nutrition received in the uterus. The question is whether the twin experiencing the nutritional deprivation indexed by low birth weight has impaired intelligence later in life.

The first study of this kind was carried out by Churchill (1965) on 22 mz twins. The birth weights of the pairs differed by an average of 260 g. The twins were tested for intelligence between the ages of 5–15 yr and it was found that the heavier twins obtained significantly higher mean IQs than the lighter (85.2 vs 80.9). A further 6 studies using this design have been reported and the results are summarised in Table 2. All the studies show IQ differences in the direction of the heavier twins at birth having higher IQs. The study by Henrichsen, Skinhoj and Andersen (1986) included measures of head circumference at birth and at the time the twins were intelligence tested. The heavier twins had greater head circumference at birth (32.8 cm vs 30.9 cm) and at age 13 (158.7 cm vs 156.4 cm) and significantly higher IQs. This study shows that suboptimal nutrition of one twin causes reduced head size at birth which is still present at the age of 13 years and is associated with lower IQ.

In addition to the twin studies, there are other types of investigation which provide further supportive evidence for an effect of nutrition on intelligence. The problem here is to control for other casual factors and a few studies have overcome this problem fairly well.

In some studies this has been done by exceptionally thorough matching of malnourished infants with controls. A good study of this kind is that of Stoch, Smythe, Moodie and Bradshaw (1982). They took 20 undernourished marasmic infants from the Coloured community in South Africa and matched them with 20 well nourished infants. The mothers of the two groups had the same socio-economic status, head circumference and mean IQ. At the age of 16 the undernourished group had a mean IQ of 56.0 and the well nourished a mean IQ of 73.5. The head circumferences of the two groups were also significantly different (undernourished: 51.7 cm; well nourished: 54.6 cm). The matching of the two groups was thorough but it may be possible to argue that there were other significant differences between the two groups, e.g. the poorly nourished group came largely from one parent families while the well nourished came from two parent families.

Some studies of the effects of malnutrition on infants have used siblings as controls for the effects of genetic and environmental factors. The methodology is to find an infant suffering from malnutrition and an unaffected sibling and test for intelligence some years later. A study of this type by Birch, Pineiro, Alcalde, Toca and Cravioto (1971) took 37 malnourished infants age 6–30

Table 2. Studies of mz twins where the heavier twin at birth obtained a higher IQ in childhood

Authors	N	Age at testing	Test	IQ difference
Churchill, 1965	22	5–15	WISC	4.3*
Kaelber and Pugh, 1969	44	6–16	Various	2.5
Scarr, 1969	25	6–10	Draw a person	9.0*
Babson and Phillips, 1973	9	13	WISC verbal	8.7*
Fujikura and Froehlich, 1974	11	4	Stanford–Binet	4.7
Fujikura and Froehlich, 1974	15	4	Stanford–Binet	1.9
Henrichsen, Skinhoj and Andersen, 1986	14	13	WISC	3.6*

Asterisks denote statistical significance at $P < 0.05$.

months suffering from kwashiorkor in Mexico. These and their unaffected siblings were tested with the WISC at the age of approx. 10 yr. At this age the malnourished children obtained a mean IQ of 68 and their siblings a mean of 81. The use of sibling controls provides reasonably convincing evidence for a permanent effect of undernutrition on subsequent intelligence.

A further persuasive study using a different methodology is that of Winick, Meyer and Harris (1975) of Korean infants adopted by American parents. One hundred and eleven Korean female babies were classified into 3 groups of malnourished, moderately nourished and well nourished on the basis of their height and weight. They were placed with American adoptive parents before the age of 3 yr. The mean IQs of the 3 groups at the age of around 10 yr were 102 (malnourished), 106 (moderately nourished) and 112 (well nourished), the difference between groups 1 and 3 being statistically significant. It is difficult to see how the results can be plausibly explained except in terms of a permanently adverse effect of poor nutrition in infancy on subsequent intelligence.

In spite of the strength of these various lines of evidence for an adverse effect of poor nutrition on intelligence, doubt of such an effect has been cast by the study of the effects of the Dutch World War II famine (Stein, Susser, Saenger & Marolla, 1972). For 6 months in the winter and spring of 1944–1945 there was a severe shortage of food in the western Netherlands. The food ration was reduced to 1144 calories and 34 g of protein per day. Males conceived and born immediately before, during and after the famine were intelligence tested approx. 19 yr later when they were conscripted into the Dutch army. At this time there were no IQ differences between these young men and those from other parts of the Netherlands unaffected by the famine.

Although this study has sometimes been considered to rule out adverse effects of maternal and early nutritional deficiencies for later intelligence, there are two reasons why it does not conclusively disconfirm the theory. Firstly, although the calorie and protein intakes were low the intakes of the essential vitamins, minerals and other nutrients may not have been critically lower than in other parts of the Netherlands. Secondly, the famine was of relatively short duration. It is possible that women store essential nutrients and can release them during pregnancy for the use of the foetus during times of shortage. Alternatively, it is possible that the foetus or young infant can recover from a relatively short period of suboptimal nutrition. These considerations make the evidence of the Dutch famine less damaging than has sometimes been supposed to the thesis that the nutrition received by the foetus or by the infant is an important determinant of intelligence.

DIFFERENTIAL INCREASES IN VERBAL–EDUCATIONAL AND VISUO–SPATIAL ABILITIES

We turn now to a puzzling feature of the secular increases in intelligence. This is that some abilities have been showing greater rates of increase than others. The most straightforward way of analysing the differential rates of secular increase of different abilities is in terms of Burt's (1949) two major group factors of verbal–educational and visuo–spatial abilities. A variety of evidence indicates that the verbal–educational abilities have been rising more slowly than the visuo–spatial. The evidence will first be summarised and some reasons for the differential rates of increase will then be proposed.

The first evidence for the differential rate of increase of the two groups of abilities was presented by Flynn (1984b) when he showed that in the United States the performance IQs' (visuo–spatial abilities) of the Wechsler tests have been increasing by approx. 4 IQ points per decade over the last half century while the verbal IQs (verbal–educational abilities) have only been increasing by approx. 2 IQ points per decade. In a subsequent paper Flynn (1987) has shown that the tendency for performance IQs to show greater gains than verbal IQs has also been present in Japan, Austria, France and West Germany.

The same differential increases have been picked up in Britain. We have found that visuo–spatial ability as assessed by Cattell's culture fair test has increased by 2.5 IQ points per decade over the period 1935–1985 (Lynn *et al.*, 1987). On the other hand, vocabulary as assessed by the Mill Hill test has increased by only 0.5 IQ points per decade over approximately the same period and the verbal–educational test used in the 1932 and 1947 Scottish surveys has increased by only 1.1 IQ points per decade over the period 1932–1986 (Lynn & Hampson, 1986; Lynn, *et al.*, 1988).

For the explanation of the greater secular increase of the visuo-spatial than the verbal-educational abilities it is proposed that two factors are operating. Firstly, the visuo-spatial abilities are more sensitive to nutritional effects than the verbal-educational abilities. Secondly, there have been social and educational changes over time which have depressed some verbal-educational abilities and enhanced some others.

Evidence that the visuo-spatial abilities are more sensitive to nutrition than the verbal-educational abilities comes from two studies of identical twins with differing birth weights. Willerman and Churchill (1967) reported data for 27 such pairs. The twins were given the WISC at a mean age of 9.6 yr. The performance IQ of the lighter twin was 5.3 points lower than that of the heavier, but there was only 0.4 points difference on the verbal scale (this difference is statistically significant). A similar result has been reported by Hendrichsen *et al.* (1986) for 14 Danish identical twins with different birth weights given the WISC at a mean age of 13 yr. There was no difference between the heavier and lighter twins on the verbal scale but on the performance scale the heavier twins obtained a mean IQ 7.1 points higher than the lighter.

Further evidence that visuo-spatial abilities are more sensitive to nutrition than verbal abilities comes from a study by Hoorweg and Stanfield (1976) in Uganda. They took 60 malnourished infants and 20 well nourished matched controls aged 8–27 months. The children were followed up between the ages of 11–17 yr. At the time of the follow-up the malnourished group had smaller height and head circumference and significantly lower scores on the block design test from the WISC, the most spatial of the WISC subtests. Their Raven's Progressive Matrices scores were also depressed, but less so than the block design. On the other hand there were no differences between the two groups on vocabulary, arithmetic, rote learning or short term memory.

Studies of malnourished children on India and in Mexico have also found that visuo-spatial abilities show greater impairment than verbal (Champakam, Srikantia & Gopalan, 1968; Cravioto, De Licardie & Birch, 1966). The same effect appears in studies of the cognitive development of babies with very low birth weight: the visuo-spatial abilities are more depressed than the verbal-educational (Klein, Hack, Gallagher & Faranoff, 1985). These studies provide direct evidence that nutritional differences have greater effects on visuo-spatial than on verbal-educational abilities. Why this should be is not clear, but it provides an explanation for the greater secular rise of the visuo-spatial abilities with improving nutrition over the last half century.

This differential effect cannot explain all the features of the secular changes in abilities. It is also necessary to postulate changes in social and educational conditions. One problem is that some abilities have been in secular decline. This is the case with verbal and mathematical aptitudes measured by the Scholastic Aptitude Test (SAT) in the United States over the period 1962–1978 (Jones, 1981), mathematical abilities of 13 yr olds in Britain from 1964–1981 (Creswell & Gubb, 1987) and of 19 yr old conscripts in Norway from 1968–1980 (Flynn, 1987). The simplest explanation for these declines is that the curricula taught in schools have changed over time and the crystallised abilities measured by these tests were taught more thoroughly in earlier periods. It may also be that there has been some decline in the motivation of school children to acquire these cognitive skills as Jones (1981) suggests.

A second set of results where social and educational changes have probably operated is the large IQ gains made by conscripts on the Progressive Matrices. These gains have been calculated by Flynn (1987) at approx. 7 IQ points per decade in the Netherlands (1952–1982) and in Belgium (1958–1967) and 10 IQ points per decade in France (1949–1974). The sampling for the first year of the French data is suspect so that the gains may be exaggerated, but the gains in the Netherlands and Belgium are clearly much greater than the increases of around 3 IQ points per decade typically found in the majority of studies. Possibly educational differences are involved here. Most of the studies of the secular increases in intelligence have been carried out on children such as 10 yr olds who have been at school at both the initial and the terminal date. The conscript data is different in so far as 18/19 yr olds have received more schooling at the later dates as a result of voluntarily remaining in school and statutory increases in compulsory education. The increases in schooling may improve the cognitive skills required to do the Progressive Matrices. This test is sometimes described as culture reduced or culture fair but the appearance of the test is deceptive. It consists largely of arithmetical and geometrical progressions in design format. These mathematical skills are learned in schools and hence the greater amount of schooling of more recent cohorts provides a reasonable explanation for the unusually large gains achieved by more recent cohorts as argued by Teasdale and Owen (1987). This would explain why younger children show gains on the Progressive Matrices of approximately the same size as found for other tests, e.g. 1.9, 3.4 and 4.0 IQ point gains per decade in Britain, Australia and Canada, respectively (Lynn & Hampson, 1986; Flynn, 1987). The large gains apparently made by younger children on the PMs in Leipsig will have to remain as a rogue result.

Flynn (1987) disputes that the greater education of 18 yr olds in more recent years could have had any effect on their greater intelligence. But there is other evidence in favour of the education hypothesis. For instance, Harnqvist (1968) reports data for 4616 Swedish 18 yr old military conscripts for whom IQs were available at the age of 13 and 18. Some left school at 13 and others continued in school until the age of 18. It was therefore possible to estimate the increase in intelligence of those who remained in school as compared with those who left, and Harnqvist estimates this increase at approx. 10 IQ points. This would bring the large gains among conscripts down to approximately the same level as those found among younger children.

NUTRITIONAL SUPPLEMENTS

If nutrition is a significant determinant on intelligence, it should follow that nutritional supplements given to poorly nourished pregnant women and to children with nutritional deficiencies should produce IQ increases. There are several studies showing that this is the case. In the United States Kugelmass Poull and Samuel (1944) administered nutritional supplements to poorly nourished 0–4 yr olds and obtained an increase of 18 IQ points. Harrell, Woodyard and Gates (1955) administered supplementary diets of thiamine, riboflavin, niacin and iron to 1200 pregnant women of poor economic status in Virginia. Their children were intelligence tested at the age of 3 and had higher IQs than a matched control group. Oski and Honig (1978) found extensive iron deficiency in a group of 24 infants aged 9–26 months in New York. Half of them were given iron supplements and registered gains in mental and physical development as compared with the remaining half which served as the control groups. Further studies showing increases in intelligence and physical development in anaemic children following iron supplements are reviewed by Evans (1985). Increases in intelligence of 3.5 IQ points have also been reported among children deficient in vitamin C following supplementation with orange juice (Kubala & Katz, 1960). Most of these studies have been carried out on infants, but Benton and Roberts (1988) have reported a 9 IQ point gain in non-verbal reasoning among normal 12–13 yr old British children given a multi-vitamin and mineral supplement over an 8 month period.

HISTORICAL TRENDS IN NUTRITION AND INTELLIGENCE

The increase of intelligence in the economically developed nations over the course of the last half century raises the question of the levels of intelligence further back in time. If mean IQs have risen by 1 SD since the 1930s, have they risen by 2 SDs since the 1880s, and was the mean IQ at this time about 70 and half the population mentally retarded?

The nutrition thesis enables is to make some reasonable conjectures on this question. The period of around 25–10,000 yr ago was the last ice-age and at this time the Caucasoid peoples of Europe and the Near East had brains of approximately the same size as today (Henneberg, Budnik, Pezacka & Puch, 1985). These peoples lived largely by hunting because plant foods were unavailable for much of the year and their meat diet evidently provided them with a high standard of nutrition and enabled them to develop their large heads and brains.

Following the recession of the ice age people evolved a new life style living in permanent village settlements with domestic animals and cereal agriculture. But although the new life style was more convenient the quality of nutrition fell and many skeletal remains show signs of rickets and other malformations caused by suboptimal nutrition (Festinger, 1983).

For the last 2000 yr data on heights of adult males in Britain have been collected by Kunitz (1987) and by Floud, Gregory and Wachter (1988). The broad trend is that height has been constant at a mean of approx. 172 cm up to the cohort born around 1930. From this date onwards height has increased. It seems reasonable to infer that brain size and intelligence were approximately stable for about 2000 yr up to around 1930 and it is only in the last half century that the increases have occurred. In the economically advanced nations the improvements in nutrition have enabled us to recover the brain size and intelligence levels of our ancestors of 25,000 yr ago. Of course this analysis ignores long term secular changes which may have taken place in the genetic and cognitive stimulation determinants of intelligence, but is nevertheless offered as an approach to the intriguing question of long term historical trends in intelligence.

ALTERNATIVE THEORIES

The strength of a theory depends to some degree on whether there are plausible alternative theories of the same phenomena. Hence a theory's strength can be enhanced by showing that there are no credible rival theories. We therefore turn now to a consideration of the three leading alternative theories of the secular rise of intelligence.

The first is proposed by Flynn (1987). He argues that the apparent increases in intelligence cannot be genuine but represent only increases in the ability to do intelligence tests, which he designates abstract problem solving ability (APSA). He argues that if intelligence had genuinely risen by 1 SD over the last half century there would be so many more highly intelligent young people around that the rise would have been obvious and intellectual achievements such as patents and scientific discoveries would have increased far more than has occurred.

It is not considered that this is a plausible argument. While some of the larger IQ gains found in some studies may be artifactual in the sense that they may be due to greater test sophistication, more highly developed narrow crystallised abilities or some unknown causes, it is considered that the increases on tests like the Wechslers and Cattell's culture fair must be considered genuine increases in intelligence. There are a number of reasons for taking this view. Firstly, it is impossible to accept the distinction between abstract problem solving ability and intelligence. The two are the same. Increases have been found in all the major components of intelligence including reasoning, verbal comprehension and the visuo–spatial abilities. It is difficult to conceive of any concept that can be designated intelligence that has remained stable while all these cognitive abilities have shown secular increases. Secondly, it is doubtful whether it is reasonable to expect people to be conscious of the increases in intelligence any more than they have been conscious of the increases of similar magnitude that have taken place in height. Thirdly, it is arguable that scientific and technological progress has been very considerable in the economically advanced nations over the last half century, consistent with the apparent increases in intelligence. Fourthly, the proportion of young people going to universities has everywhere increased greatly over the last half century without it being generally considered that there has been any decline in standards. Fifthly, with genuine rises in intelligence there should have been a reduction in the prevalence of mild mental retardation, i.e. of those in the IQ band 50–70. There is some evidence that this is the case. In a recent prevalence study in Sweden, Hagberg, Lewerth, Olsson and Westerberg (1987) found only 0.38% of adolescents with mild mental retardation, far fewer than the expected 2.1%. For these reasons it is considered that the IQ gains are genuine.

The second alternative theory to the nutrition thesis of the increases in intelligence is that these gave been due to improvements in cognitive stimulation. This would come from parents who are better educated, better able to provide cognitive stimulation, from smaller families, greater availability of radio, television and educational toys, and possibly from improvements in education.

At first sight cognitive stimulation theory seems to provide a plausible explanation for the increases in intelligence. There are, however, two cogent arguments against it. Firstly, improvements in cognitive stimulation would be expected to act most strongly on the verbal–educational abilities which are learned formally and informally in the family and in schools, and least strongly on the visuo–spatial abilities. The verbal IQs of the Wechsler are more highly correlated than the performance IQs with socio-economic status (0.21 and 0.08 respectively in the calculation of Jensen & Reynolds, 1982). Similarly in Dumaret's (1985) adoption study in France in which lower class infants were adopted by professional families and compared with their half siblings who remained with their biological mothers, the adopted siblings at the age of approx. 9–10 yr showed a 20 IQ point superiority in the verbal scale of the WISC but only an 8 IQ point superiority on the performance scale. The most straightforward interpretation of these results is that the better cognitive stimulation provided by higher SES parents acts more strongly on the verbal abilities. This is further supported by the results of Burks (1928) and Scarr and Weinberg (1976) that the adopting parent–adopted child correlation for vocabulary is higher than for other abilities. This evidence indicating that the better cognitive stimulation provided by professional or middle class families acts more strongly on the verbal abilities leads to the expectation that if secular improvements in cognitive stimulation have been the factor responsible for the secular increases in intelligence it is the verbal abilities which should have shown the greater increases. Yet, as we have noted, this is not the case. The verbal–educational abilities as a whole have shown quite small secular increases and some of the crystallised educational abilities, such as those tested in the SAT, have even shown secular decline. It is the visuo–spatial abilities which are less taught in families and schools which have shown the greatest increases. While these differential rates of increase of the verbal–educational and visuo–spatial abilities are contrary to prediction from cognitive stimulation theory, they follow from nutrition theory and are consistent with findings that the visuo–spatial abilities are more sensitive to nutritional improvements, as noted above.

The second argument against a cognitive stimulation theory of the secular increases in intelligence is that these increases have occurred among very young children. The Griffiths scale of mental development is an intelligence test for 0–2 yr olds measuring locomotion progress, personal–social behaviour and vocabulary. The test was standardized in Britain in 1950 and in 1980 a nationally representative sample was tested. The mean IQ had risen 10.2 IQ points over the 30 yr period, almost exactly the rate of increase of intelligence found for older children and adolescents. Even infants in the first few months of life showed the same accelerated development (Hanson, Smith & Hume, 1985).

Studies in the United States using the Bayley scales of infant development have also shown a similar secular trend of faster motor development among 1 yr old infants over the last half century (Knoblock, Stevens & Malone, 1980; Capute, Shapiro, Palmer, Ross & Wachtel, 1985). These secular increases in motor and mental development among infants in the age range of 6–24 months throw doubt on possible improvements in cognitive stimulation as the factor responsible for the intelligence increases among later age groups. It is questionable whether cognitive stimulation has much effect on the motor development of 1 yr olds. The increases in development quotients at these early ages suggest neurological improvement in brain function and bring us back to nutrition as the most plausible factor responsible for the secular increases in intelligence.

A third theory of the secular increases in intelligence that deserves consideration is that these may be due to genetic factors. There are two possibilities. The first is that there could have been a tendency for more intelligent individuals to have had more children. The most extensive data on this question on approx. 12,000 *S*s in the United States found consistently negative correlations between fertility and intelligence (Van Court & Bean, 1985). It is improbable that the relationship has been positive in other economically developed nations and therefore the eugenic hypothesis can almost certainly be ruled out.

A second possible genetic effect could consist of an increase in outbreeding (heterosis). There has probably been some increase in outbreeding over the last half century as societies have become more urbanised. However, the magnitude of any possible effects on intelligence would appear to be small. The inbreeding depression effect on the intelligence of the offspring of first cousins amounts to about 5 IQ points (Jensen, 1983). The amount of inbreeding in the populations of the economically advanced nations in the 1930s would have been nowhere near that of first cousins, so any effect of some increase in outbreeding on the secular increase of intelligence would be minute. Furthermore, it has been shown by Jensen (1983) that the effects of inbreeding on intelligence are to decrease *g* (general intelligence) and verbal intelligence but to increase the visuo–spatial abilities. It follows that a secular trend of reduced inbreeding should produce increases in *g* and the verbal abilities and decreases in the visuo–spatial abilities. Yet, as has been noted, it is the visuo–spatial abilities that have shown the largest secular increases. This reinforces the conclusion that possible secular increases in heterosis can have had no appreciable effect on the increases in intelligence.

POTENTIAL FOR FURTHER INCREASES IN INTELLIGENCE

The secular increases in intelligence that have taken place over the last half century have shown little or no tendency to diminish in the last 10 or 15 yr. In Britain we have found intelligence gains among 8–14 yr olds of 3.3 IQ points on the verbal and non-verbal reasoning scales of the Cognitive Abilities Test over the recent period 1972–1984 (Lynn & Hampson, 1989). It appears that intelligence is still on an upwards trajectory. It seems reasonable to assume that this trend can be projected into the future and that further intelligence increases can be anticipated.

These increases in intelligence in the recent past have been paralleled by similar recent gains in height. In Britain the height of 11 yr olds increased by approx. 1 cm over the period 1972–1981 and similar increases have been found in recent years in the Netherlands (Rona & Chinn, 1984; Roede & Van Wieringen, 1985). These increases suggest that in the quite recent past nutrition has been suboptimal for substantial proportions of the population.

This inference is confirmed by nutrition surveys. In Britain a study by Benton & Roberts (1988) reported a third of adolescents were not obtaining the recommended intake of a number of the essential vitamins and nutrients including vitamins A, B12, D and E, and folic acid, calcium, chromium, copper, iodine, iron, magnesium and zinc.

Black, Wiles and Paul (1986) have found deficiencies in vitamins B6, D and E, zinc, copper, folate biotin and iron in the diets of pregnant women. In the Netherlands deficiencies in the intake of iron, polyunsaturated fatty acids and polysaccharides among adolescents have been reported by Post, Kemper and Storm-van Essen (1987). In the United States it has been estimated that about 9% of children are chronically short of a number of essential nutrients (Brown, 1987). Deficiencies in vitamins A and C and in iron have been found in 20–50% of the population (Oski & Honig, 1978; Schorr, Sanjur & Erickson, 1972; Raica, Scott, Lowry & Sauberlich, 1972; Frank, Voors, Schilling & Berenson, 1977).

The survey evidence of widespread suboptimal nutrition is confirmed by the presence of socio-economic differences in height. These differences were first noted in the early nineteenth century in France by Villermé (1829) who attributed them to differences in nutrition. In Britain there were still mean differences in height of approx. 2 cm between children in SES 1 and 5 (professional vs unskilled workers) in the early 1980s (Wenlock, Disselduff, Skinner & Knight, 1986; Rona & Chinn, 1984). Similar differences have been found in recent studies in Denmark and the Netherlands (Jansen, 1982; Roede & Van Wieringen, 1985). It is difficult to explain these socio-economic differences in height except as an effect of suboptimal nutrition among the poorer social classes and their continued existence is further testimony to the presence of widespread undernutrition among substantial sections of the populations of the economically developed nations. It seems probable that with increases in living standards nutrition is likely to improve and there will be further increases in both height and intelligence.

CONCLUSIONS

The objective of this paper has been to offer an explanation for the secular increases in intelligence which have taken place in the economically developed nations over the last half century. The theory is that these are principally due to improvements in nutrition. It is proposed that the parallel increases that have taken place in height and head size, the positive association between height, head size and intelligence, and the evidence that suboptimal nutrition reduces height, head sizes and intelligence, all support a nutrition theory of the increases in intelligence. It is proposed further that there is no credible alternative theory.

The continued increases in both height and intelligence in the 1970s and 1980s suggest that nutrition has been suboptimal for substantial proportions of the population in the quite recent past. This is confirmed by nutrition surveys and the continued existence of socio-economic status differences in height. There is therefore reason to believe that there is scope for improvment in nutrition and that this will be followed by further increases in height, head size and intelligence.

Our analysis of the major role played by improvements in nutrition in the secular increases in intelligence suggests that nutrition is a more important determinant of intelligence than is generally supposed. It has been widely assumed that cognitive stimulation is the major environmental determinant of intelligence. Thus, the headstart programs designed to raise the IQs of preschool children have concentrated their efforts on the provision of cognitive stimulation either in preschools or by mothers given advice and training. These programs have had generally disappointing results and although some temporary gains have been registered there appear to be no long term benefits (Bronfenbrenner, 1974; Darlington, Royce, Snipper, Murray & Lazar, 1980). Perhaps this problem would be better attacked through improvements in nutrition. It may be time for governments to take a more active role in securing better nutrition, perhaps by providing nutritional supplements to pregnant women and to children. This would yield a valuable social return. Intelligence is a major determinant of educational attainment, employment, occupational success, scientific and cultural achievements and (negatively) of crime. The increases in intelligence that can be anticipated if further improvements in nutrition could be secured should yield significant social benefits.

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