Intelligence xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Intelligence

journal homepage:

The social and scientific temporal correlates of genotypic intelligence and the Flynn effect

Michael A. Woodley

Ross University School of Medicine, Dominica

ARTICLE INFO

Article history:
Received 12 October 2011
Received in revised form 22 December 2011
Accepted 23 December 2011
Available online xxxx

Keywords:
Dysgenesis
Flynn effect
Innovation rates
Life history
Population cycle

ABSTRACT

In this study the pattern of temporal variation in innovation rates is examined in the context of Western IQ measures in which historical genotypic gains and losses along with the Flynn effect are considered. It is found that two alternative genotypic IQ estimates based on an increase in IQ from 1455 to 1850 followed by a decrease from 1850 to the present, best fitted the historical growth and decline of innovation rates ($r=$ .876 and .866, $N=56$ decades). These genotypic IQ estimates were found to be the strongest predictors of innovation rates in regression in which a common factor of GDP (PPP) per capita and Flynn effect gains along with a common factor of illiteracy and homicide rates were also included ($\beta=.706$ and .787, $N=51$ decades). The strongest temporal correlate of the Flynn effect was GDP (PPP) per capita ($r=.930$, $N=51$ decades). A common factor of these was used as the dependent variable in regression, in which the common factor of illiteracy/homicide rates was the strongest predictor ($\beta=-1.251$ and -1.389, $N=51$ decades). The genotypic IQ estimates were significant negative predictors of the Flynn effect ($\beta=-.894$ and $-.978$, $N=51$ decades). These relationships were robust to path analysis. This finding indicates that the Flynn effect, whilst associated with developmental indicators and wealth, only minimally influences innovation rates, which appear instead to be most strongly promoted or inhibited by changes in genotypic intelligence.

1. Introduction

Many individuals have attempted to predict the future, some in a non-scientific manner (e.g. via religion) and some in a scientific manner. Those who identify with the scientific tradition today use the label of futurology to describe their efforts and employ a variety of techniques in "divining" future social and scientific trends. There is no clear consensus amongst futurologists as to what the future will be like, with some predicting social and scientific stagnation and possibly also decline (e.g. Cowen, 2011; Horgan, 1997; Huebner, 2005a), and others predicting massively accelerated growth in science, technology and knowledge. Those in the latter camp have coined a word to describe this hypothetical future in which accelerating returns from technological progress fundamentally alters both human society and nature — *singularity* (after the exponential function). Singularity is to be achieved through the development of technologies such as human-like artificial intelligence (AI) and biological immortality which will (ideally) recursively enhance and empower human capabilities (Drexler, 1992; Kurzweil, 2004; Vinge, 1993).

Here it will be demonstrated that essential to any attempt at understanding and predicting changes in innovation is knowledge of the ways in which intelligence has changed over the course of the centuries, and indeed might continue to change in the future. This is especially important as a number of researchers have identified significant associations between scientific and technological achievement and IQ both at the individual differences (e.g. Lubinski, Benbow, Webb & Bleske-Rechek, 2006) and country-level scales (e.g. Gelade, 2008; Rindermann, Sailer, & Thompson, 2009; Rindermann & Thompson, 2011).

E-mail address: MWoodley@rossmed.edu.dm.

0160-2896/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.intell.2011.12.002

In this paper, after a review of the dysgenesis and Flynn effect literatures, historical trends in a number of key indicators including genotypic intelligence, the Flynn effect, and GDP (PPP) per capita amongst others will be analyzed in an effort to identify the key predictors of trends in science and technology. In the context of this the two main models of the future of science and technology (i.e. stagnation/decline and accelerating returns) will be assessed in terms of plausibility.

1.1. Has IQ changed over time?

1.1.1. Dysgenesis

Dysgenesis describes the tendency for a heritable and socially valued trait (such as intelligence) to decline over time within a population as a result of differential fertility disfavouring the trait. Galton (1869) was one of the first to discuss the phenomenon and also to use the term, although he lacked a sufficiently sophisticated method of intelligence measurement to effectively quantify it.

Early in the 20th century, negative correlations were observed between intelligence and fertility, which were taken to indicate a dysgenic fertility trend (e.g. Cattell, 1936; Lentz, 1927; Maller, 1933; Sutherland, 1929). Early predictions of the rate of dysgenesis were as high as between 1 and 1.5 IQ points per decade (Cattell, 1937, 1936). However, the longitudinal study of Maxwell (1954) conducted between 1932 and 1947, which employed the Scottish Survey, found the opposite — namely that IQ had *increased* by around 2.3 points in 15 years. Cattell (1951) also reported a 1.2 point increase in mean IQ amongst English 10-year old samples tested in 1936 and also in 1950.

A variety of theories were proposed to account for these contradictory findings, namely, that intelligence was increasing despite the fact that less intelligent individuals were having more children. Some of these theories foreshadowed modern explanations for the Flynn effect by stressing environmental factors such as education and improved communications (Tuddenham, 1948). One theory emphasized the supposed eugenic fertility enhancing properties of democracy (Osborn, 1940).

Studies conducted on cohorts reproducing during the 'baby boom' years (late 40s and 50s) typically found *positive* correlations between IQ and completed fertility (see van Court & Bean, 1985 for an overview). This led to speculation that eugenic fertility for intelligence was rather the norm than the exception (Falek, 1971; Osborn & Bajema, 1972). Subsequent research cast doubt on the relevance of these studies owing to the limited range of locations from which the samples were sourced, and also the narrow range of birth cohorts considered (e.g. Cattell, 1974; Jensen, 1969; Vining, 1982). Vining (1982) argued that the correlation between IQ and fertility should be either neutral or positive during periods of rising fertility, but negative during periods of declining fertility — which characterize the years on either side of the 'baby boom'. In their study of the relationship between intelligence and both completed and partially completed fertility, van Court and Bean (1985) reported that the relationships were predominantly negative in cohorts born between the years 1912 and 1982. They argue that reports of apparent eugenic fertility might have been restricted to specific cohorts living in specific regions.

A variety of studies have presented estimates of genotypic IQ declines for a variety of populations. Here genotypic IQ is defined as the intelligence that people exhibit if they have access to optimal environments. This is distinct from phenotypic IQ, which is observed and measured IQ resulting from the influence of both genetic and environmental factors (Lynn, 1996). Vining (1982) was the first to have attempted an estimation of the rate of genotypic IQ decline due to dysgenesis with reference to a large national probability cohort of US women aged between 24 and 34 years in 1978. He identified significant negative correlations between fertility and IQ ranging from −.104 to −.221 across categories of sex, age and race, with an estimated genotypic IQ decline of one point a generation. In a 10-year follow-up study using the same cohort, Vining (1995) re-examined the relationship between IQ and fertility, now that fertility was complete, finding evidence for a genotypic IQ decline of .5 points per generation.

Retherford and Sewell (1988) examined the association between fertility and IQ amongst a sample of 9000 Wisconsin high-school graduates (graduated 1957). They found a selection differential that would have reduced the phenotypic IQ by .81 points per generation under the assumption of equal IQs for parents and children. With an estimate of .4 for the additive heritability of IQ, they calculated a more modest genotypic decline of approximately .33 points.

The study of Ree and Earles (1991), which employed the NLSY suggests that once the differential fertility of immigrant groups is taken into consideration, the phenotypic IQ loss amongst the American population may be greater than .8 of a point per generation. Similarly, in summarizing various studies, Herrnstein & Murray (1994) suggest that "it would be nearly impossible to make the total [phenotypic IQ decline] come out to less than one point per generation. It might be twice that." (p. 364).

Loehlin (1997) found a negative relationship between the fertility of American women aged 35–44 in 1992 and their educational level. By assigning IQ scores to each of six educational levels, Loehlin estimated a dysgenesis rate of .8 points in one generation.

Significant contributions to the study of dysgenesis have been made by Lynn, 1996 (see also: 2011) whose book *Dysgenics: Genetic deterioration in modern populations* provided the first estimates of the magnitude of dysgenesis in Britain over a 90 year period, putting the phenotypic loss at .069 points per year (about 1.7 points a generation assuming a generational length of 25 years). In the same study, Lynn estimated that the genotypic IQ loss was 1.64 points per generation between 1920 and 1940, which reduced to .66 points between 1950 and the present. Subsequent work by Lynn has investigated dysgenesis in other populations. For example Lynn (1999) found evidence for dysgenic fertility amongst those surveyed in the 1994 National Opinion Research Center survey, which encompassed a representative sample of American adults, in the form of negative correlations between the intelligence of adults aged 40+ and the number of children and siblings. Lynn estimates the rate of dysgenesis amongst this cohort at .48 points per generation. In a more recent study, Lynn and van Court (2004) estimated that amongst the most recent US cohort for which fertility can be considered complete (i.e. those born in the years 1940–1949), IQ has declined by .9 points per generation.

Please cite this article as: Woodley, M.A., The social and scientific temporal correlates of genotypic intelligence and the Flynn effect, *Intelligence* (2012), doi:10.1016/j.intell.2011.12.002

At the country level, Lynn and Harvey (2008) have found evidence of a global dysgenesis of around .86 points between 1950 and 2000, which is projected to increase to 1.28 points in the period from 2000 to 2050. This projection includes the assumption that 35% of the varience in cross-country IQ differences is due to the influence of genetic factors. A subsequent study by Meisenberg (2009), found that the fertility differential between developed and developing nations has the potential to reduce the phenotypic world population IQ mean by 1.34 points *per decade* (amounting to a genotypic decline of .47 points per decade assuming Lynn & Harvey's 35% estimate). This assumes present rates of fertility and pre-reproductive mortality within countries.

Meisenberg (2010) and Meisenberg and Kaul (2010) have examined the factors through which intelligence influences reproductive outcomes. They found that amongst the NLSY79 cohort in the United States, the negative correlation between intelligence and fertility is primarily associated with *g* and is mediated in part by education and income, and to a lesser extent by more “liberal” gender attitudes. From this Meisenberg has suggested that in the absence of migration and with a constant environment, selection has the potential to reduce the average genotypic IQ of the US population by between .4, .8 and 1.2 points per generation.

Nyborg (in press) has developed what he terms a “decay model”, which permits historical and future declines in IQ to be estimated. The model is based on the idea that dysgenesis in Western nations stems from two factors. The first is the internal relaxation (or reversal) of Darwinian selection (IRDS),[1] which includes factors associated with modernity such as health-care, education and contraceptives that have differentially reduced the fertility of those with high IQs relative to those with low IQs (e.g. Lynn, 1996, 2011; Udry, 1978). The second is the external relaxation of Darwinian selection (ERDS), which reduces the average IQ of high IQ countries through immigration from low IQ countries. These combine to create a composite “double” relaxation of Darwinian selection pressure (DRDS) score.

Whilst the scores are based on decline estimates derived from British and Danish populations, it is known that these trends are paralleled not only throughout the West, but globally also, owing to the existence of dysgenic fertility differentials in all measured nations (Meisenberg, 2008). Another assumption of the model is that dysgenesis in the West commenced in the first half of the 19th century. This is a reasonable assumption given the large body of research (e.g. Clark, 2007; Clark & Hamilton, 2006; Galor & Moav, 2002; Lynn, 2011; Pettay, Helle, Jokela, & Lummaa, 2007; Razi, 1980; Skjærvø, Bongard, Viken, Stokke, & Røskaft, 2011; Weiss, 1990), which has found that the demographic expansion of the middle classes in England and elsewhere from the 12th century to the 1800s was principally associated with differential fertility favoring those with “bourgeois” traits such as predisposition towards non-violent behavior, lower time preference, and also g (Figueredo, 2009; Rindermann, 2009). These individuals came to replace the lower classes via downward social mobility until the 19th century, at which point their descendants had come to account for the majority of the Western population (Clark, 2007; Frost, 2011; Weiss, 2008). In an analysis of the status-fertility relationship using a large dataset, Skirbekk (2008) demonstrates that in the period from 1800 to 1850 all Western countries transitioned into negative fertility for social status. By the middle of the 20th century, Latin America, Africa, and the Middle East had also made this transition.

1.1.2. The Flynn effect

A countervailing trend to dysgenesis is the Flynn (also Lynn–Flynn) effect. This effect is associated with a sharp secular increase in IQ scores of approximately three points per decade over the last 60 years or so, with the biggest gains having been recorded in countries during the 30 year post World War II recovery period (Flynn, 1987, 2009a). There is much debate over the cause and the meaning of the Flynn effect. Its rapidity suggests an environmental basis, and several such causes have been proposed over the years, including nutrition (Lynn, 1989, 2009), education (Husén & Tuijnman, 1991; Teasdale & Owen, 1989; Tuddenham, 1948), diminution of pathogen stress (Eppig, Fincher, & Thornhill, 2010), and social multipliers which are associated with the tendency for cognitive stimulation to raise the ambient intelligence level such that there is greater demand for successively more cognitive stimulation (Dickens & Flynn, 2001).

Not all psychometricians agree that the Flynn effect constitutes a real increase in ability; indeed it has been argued that the effect might stem from tests losing their *g*-loadings as a function of retesting and general familiarity (Brand, 1987, 1990; Brand, Freshwater, & Dockrell, 1989; Jensen, 1996; Rodgers, 1998; Rushton & Jensen, 2010). A handful of studies have found evidence that the Flynn effect has been associated with a real world increase in at least some aspects of intelligence. Two studies by Howard (1999, 2001) have presented evidence that the effect may have been associated with an increase in the degree to which younger players have come to dominate intellectual games (such as chess since the 1970s, and to a lesser extent bridge and go), the apparent decrease in the prevalence of mild mental retardation in the US and elsewhere and the apparent increase in scientific productivity as measured by number of journal articles and patents awarded. Also evidence is presented in the form of the perceptions of teachers, who report that the practical abilities of students may have increased since 1979, although apparently not their general intelligence. Cocodia et al. (2003) have observed that in Asian nations, teachers report that students have been getting brighter over the last 30 years; however, they also found that in Western nations teachers did not perceive a similar increase in intelligence.

A significant point of contention concerns whether or not the Flynn effect reflects changes in a population's level of *g*. The high broad sense heritability of *g* (Gottfredson, 1997a; Neisser et al., 1996) suggests that it should exhibit low susceptibility to environmental influences (i.e. the range of 'acceptable' environments for g should be very broad). This has led Mingroni (2004, 2007) to connect the Flynn effect with heterosis (hybrid vigor), which he contends occurred in the West and elsewhere over the last 50 or so years owing to the

[1] It is not accurate to describe a dysgenic trend as resulting of the relaxation of selection. The fact that gene frequencies for intelligence and other traits are changing indicates a selective pressure, even if from a strictly human standpoint, the direction of change might be considered socially less desirable. From an evolutionary perspective it is the carriers of the genes for traits such as high-IQ which are at a disadvantage, as their fitness is evidently currently disfavoured by selection.

Please cite this article as: Woodley, M.A., The social and scientific temporal correlates of genotypic intelligence and the Flynn effect, *Intelligence* (2012), doi:10.1016/j.intell.2011.12.002

break-up of relatively inbred communities. It has been observed however that Mingroni's model suffers from a number of weaknesses, such as the observation that his simulated IQ gains over the course of 50 years are on the order of three points, whereas the Flynn effect is associated with IQ gains on the order of three points *per decade* (Flynn, 2009a; Lynn, 2009). Furthermore a number of studies seem to have produced evidence directly disconfirming the involvement of heterosis in the Flynn effect (for a review see: Woodley, 2011a).

Another problem is that the Flynn effect doesn't appear to be associated with changes in the level of *g*. Instead, it is associated with heterogeneous gains in specific abilities (Wicherts et al., 2004) coupled with a general weakening of the strength of *g* over time (Juan-Espinosa, Cuevas, Escorial, & García, 2006; Kane, 2000; Kane & Oakland, 2000; Lynn & Cooper, 1993, 1994). This has led to the development of a new model of the Flynn effect based on the cognitive differentiation–integration effort (CD–IE) hypothesis (Woodley, 2011b). The CD–IE hypothesis posits that variation in the strength of the positive manifold is regulated by life history — individual differences in the fundamental pattern of bioenergetic trade-offs between the domains of mating, parenting and maintenance which allow organisms to adapt their fitness to the demands of either unstable or stable environments (Figueredo, Vásquez, Brumbach, & Schneider, 2004). "Slow" life history (high parenting and maintenance effort) individuals exhibit differentiated abilities and cognitive specialisms as an adaptation to intra-specific competition, which is characteristic of populations living at the carrying capacity of stable environments. "Fast" life history (high mating effort) individuals on the other hand need much more strongly integrated abilities in order to cope with unstable environments and unpredictable people. Cognitive generalism permits these fast life history "Jacks of all trades" to develop the sorts of domain general skills needed to move with relative ease between socio-ecological niches, which buffers against instability. Furthermore it allows them to generate better "multidimensional" indicators of fitness, which aids in the short term mating market. The CD–IE hypothesis posits that this life history trade-off between cognitive specialism and generalism occurs largely independently of the level of "genetic *g*", which is equated instead with neural efficiency and plasticity, owing to the lack of a substantive correlation between g and the *K* factor latent in life history measures (Woodley, 2011b).

As evidenced by indicators such as diminishing total fertility rates and enhanced longevity, people in the developed world have been experiencing significant life history slowing. This process has been termed the demographic transition. Potential facilitators of the demographic transition include factors such as environmental stability brought about by increased economic security, improved nutrition, the diminution of pathogen stress (all three of which would have reduced adult and infant mortality) and education (which has a significant negative impact on female fertility). Declining family sizes have encouraged the consolidation of more resources into fewer offspring — i.e. greater parenting effort (Mace, 1999; Woodley, in press). Their impact on life history speed could have been mediated by mechanisms associated with developmental plasticity (Del Giudice & Belsky, 2011; Ellis, Figueredo, Brumbach, & Schlomer, 2009), which is consistent with the observation that life history exhibits a modest environmentality (about e^2~.35) (Figueredo et al., 2004). Slower life history individuals possess lower time preferences and are therefore more inclined to spend many years expending effort in developing cognitive specializations, typically through schooling or the acquisition of vocational skills (Woodley, 2011a, b, in press). Not only does the life history model provide a framework within which the influences of diverse developmental variables can be reconciled, but it permits a novel resolution of the apparent contradictions between dysgenesis and the Flynn effect. This is because lower heritability abilities can be bought into and out of correlation with one another independently of a population's level of "genetic *g*" (i.e. overall neural efficiency and plasticity), which is therefore free to decline due to negative directional selection. Consistent with this, it has been found that dysgenesis occurs predominantly on *g* rather than specific abilities (Meisenberg, 2010; Meisenberg & Kaul, 2010).

Given the apparent significance of IQ for the technological and scientific achievement of both individuals and nations, an important question to ask is, what effect might historical fluctuations in IQ have had on scientific and technological output over time? Is the historical record of scientific and technological innovation consistent with dysgenesis or the Flynn effect? Here we will attempt to address these questions through the use of correlative, regression and path analysis.

2. Methods

2.1. Measuring changing innovation rates

Innovation rates were obtained from Huebner (2005a), who defines this variable in terms of the number of important scientific and technological developments per year divided by the world population. This metric therefore captures the innovative capacity of populations on a yearly basis. In developing his innovation rate measures Huebner obtained a list of 7198 important events in the history of science and technology compiled by Bunch and Hellemans (2004), which spans from 1455 to 2004. By curve-fitting these data to a Gaussian distribution, Huebner attempts to predict future innovation rates out to the 22nd century. Huebner's historical and future world population estimates were derived from the U.S. Census Bureau (2004a, 2004b). The estimates were available on a decadal basis and were obtained from Huebner's Fig. 1 (p. 982).

Huebner draws a distinction between fundamentally new technologies (what could be termed macroinnovations) and improvements in existing technologies (what could be termed microinnovations). He illustrates this distinction with reference to Bunch and Hellemans (2004) inclusion of 37 separate events involving space shuttle missions launched between 1981 and 2003, which he argues could reasonably be regarded as simply microinnovation around an unambiguous macroinnovation (i.e. the development of the space shuttle itself). Huebner stresses however that exclusion of these potential microinnovations would actually serve to potentiate the observation of a recent decline in innovation rates, hence his estimates must be considered conservative.

A potential objection to Huebner's estimates is that they might lack validity owing to potential subjective bias on the part of Bunch and Hellemans (Coates, 2005; Modis, 2005; Smart, 2005; cf Huebner, 2005b). A simple test of the reliability of Huebner's estimates would involve correlating them with other estimates derived from other independently compiled inventories, thus determining their convergent validity. Murray (2003, p. 347) provides data on the frequency of significant events in the history of science and technology between the years 1400 and 1950. Murray's index is computed on the basis of the weighted percentage of sources (i.e. multiple lists of key events in the history of science and technology), which include a particular key event. Although Murray's data are not as extensive in time as are Huebner's, it is apparent that rate of accomplishment increases commensurately with Huebner's index in the period from 1455 to the middle of the 19th century, and then declines towards the end of that century and into the 20th. Murray's index was found to correlate highly with Huebner's ($r = .865$, $P < .01$, $N = 50$ decades). In an earlier unpublished study, Gary (1993) computed innovation rates using Asimov's (1994) Chronology of Science and Discovery. He found the same shaped curve as that described by both Huebner and Murray, with an innovation peak occurring at the end of the 19th century. Huebner's index correlates strongly with Gary's ($r = .853$, $P < .01$, $N = 21$ time points). It should be noted that the observation of peak innovation at the end of the 19th century dates back to the work of Sorokin (1942), thus it is concluded that Huebner's index exhibits high convergent validity. It is used here in preference to other indices owing to the fact that it is based on a more comprehensive innovation inventory and is available for more time points than are the other indices.

A second potential objection to Huebner's index concerns it's use of the world population in generating per capita innovation rate estimates. It has been argued that because the majority of major innovations originated from Western countries (i.e. Europe and North America), the inclusion of developing countries with booming populations exaggerates the post 19th century decline in innovation rates (Coates, 2005; Modis, 2005; cf Huebner, 2006). To control for this Huebner's critics suggest re-estimating innovation rates using just the innovation-generating countries. This analysis was conducted using raw decadal innovation data from Bunch and Hellemans (2004), along with data on European population growth from 1455 to 1995 (from McEvedy & Jones [1978] and the US Census Bureau) combined with data on US population growth from 1795 to 1995 (from various statistical abstracts of the United States available from the US Census Bureau). The resultant innovation rates were found to correlate at $r = .927$ ($P < .01$, $N = 55$ decades) with Huebner's original estimates, which indicates that the innovation rate data are insensitive to decision rules concerning which set of population estimates are used. Where choice of population matters is in extrapolating future declines in innovation rate. The rate of population growth amongst Western nations is rapidly stagnating and may go into reverse in a couple of decades, whereas the populations of the developing world by comparison are predicted to account for an increasingly large share of global population growth. Therefore Huebner's innovation rates will be used up to 2005 (representing an N of 56 decades), and future projected innovation rates will not be used.

2.2. Cross-temporal IQ data

2.2.1. Estimating changes in genotypic IQ

No IQ data exist for populations living between the 15th and the middle of the 19th century. However it may be possible to estimate historical IQs based on the use of certain proxies. Therefore, in order to estimate the IQ of European populations living in 1455, table 17.1 in Hart (2007, p. 124) was employed. In his book *Understanding Human History* Hart employs a computer model to estimate the change in genotypic IQ amongst various populations over the last 70,000 years. The model assumes that IQ has increased as a linear function of the degree of "harshness" encountered by a population, and despite its simplicity it does a good job at approximating the current distribution of national IQs. He lists a European mean of 89.5 for 5000 years ago (derived from averaging his Northern and Southern European means). Assuming a contemporary European mean of approximately 100, the gradient of the slope between the two numbers could be used to ascertain the rate of IQ increase per year. From this an estimate of 1455 European genotypic IQ of 96.95 was derived. The idea that Europe in the Middle Ages exhibited a lower average genotypic IQ than today is compatible with the observation that middle class traits (which would have included higher g) were subject to positive directional selection during the Middle Ages up to the 19th century.

Western genotypic IQ estimates from 1850 to 2075 are available from Nyborg (in press). Lynn (1996) has estimated a phenotypic IQ decline over 90 years for Britain of .069 points per year. Using Nyborg's decay model, multiplying this number by 160 years yields the total Western selection differential to the present day (this model assumed no Flynn effect and also no regression to the mean). Multiplying the number by a further 61 years yields the projected differential through to the year 2072. If that figure is then multiplied by the heritability of IQ (Nyborg uses Lynn's (1996) estimate of .82) the net Western genotypic IQ decline due to IRDS can be estimated, which along with ERDS estimates can be used to calculate DRDS.

Table 1 illustrates the procedure used by Nyborg in calculating dysgenesis rates. The numbers used here are different from those used in his original paper as the application of the formula yielded slightly different results in some cases. The differences are negligible, however it must be noted that there are issues with some aspects of Nyborg's methodology. For example, Nyborg relies upon Lynn's (1996) heritability estimate of .82 in attempting to calculate ERDS with respect to non-European populations.

Table 1
Western dysgenesis rates from 1850 to 2072 (modified from Nyborg, in press). Shown are changes in IQ for the time periods indicated. The selection differential is the phenotypic decline that would be observed if children had the same average IQ as their parents.

Source of IQ decline	1850–1978	1979–2010	2011–2072	Selection differential (1850–2072)	Genotypic decline (selection differential multiplied by .82)
IRDS	−8.90	−2.10	−4.21	−15.21	−12.47
ERDS	–	−.90	−5.10	−6.00	−4.90
DRDS	−8.90	−3.00	−9.31	−21.21	−17.39

As was mentioned in the introduction, at the country level, Lynn and Harvey (2008) have offered a more conservative estimate of .35 for the genetic determination of international IQ differences, based on the reasonable assumption that between populations, environmental factors play a much more significant role in influencing IQ. Applying Lynn and Harvey's alternative estimate yields lower estimates for ERDS (2.1), with a total DRDS of around 15.57.

Despite the ambiguities in Nyborg's methodology, these estimates could be described as representing the potential upper bound of dysgenesis (with an 1850 genotypic IQ of 109.5). A number of estimates suggest that the decline is on the order of between 0.8 and around 1 point a generation (Loehlin, 1997; Lynn, 1996, 2011; Lynn & van Court, 2004; Vining, 1982). The most recent studies are those of Meisenberg (2010) and Meisenberg and Kaul (2010), who, using the NLSY79 cohort, have estimated a dysgenesis rate on *g* of approximately one point per generation (the average of .4, .8 and 1.2 is .8), which if generalized for the West, would suggest an 1850 genotypic IQ mean of about 105 (assuming approximately five generations and allowing for generational lengthening). Nyborg's estimates will therefore be used here as an upper limit along with more conservative estimates based on Meisenberg's (2010) and Meisenberg and Kaul's (2010) findings.

Genotypic IQ levels are estimated at decadal intervals between each period (1455–1850, 1850–1978, and 1978–2005) by deriving the yearly gain or loss of IQ from the gradient of the slope between each period.

In order to explore the external validity of these genotypic IQ estimates, a test was performed using data from Skirbekk (2008, p. 157), who lists the relative fertility of high status vs. low status groups from Europe and North America for various intervals (before 1750, 1750-1899, 1900-1924, 1925-1949, 1950-1974, 1975-1989 and 1990-2006). These measures were correlated with the selective differential on genotypic IQ for each interval. In both cases the correlations were $>.9$ ($P<.01$, $N=7$ intervals), indicating a subatantive relationship. It is important to note that long-term constant increases and decreases in genotypic IQ are assumed for the purposes of this model. A number of factors might have resulted in dysgenesis rates behaving somewhat more stochastically at finer scales however, including the influence of warfare along with political murder and genocide (such as was practiced by totalitarian regimes) (e.g. Glad, 1998, Itzkoff, 2009). Furthermore the strength of IRDS may have been greater in the first half of the 20th century, relative to the second (Lynn, 1996; 2011). Some ‘baby boomer’ cohorts may also have experienced less dysgenic fertility relative to other cohorts (e.g. van Court & Bean, 1985). Whilst these factors need to be incorporated into more precise future estimates of dysgenesis rates, the general tendency since the mid 19th century in Western nations has undoubtedly been one of negative selection for genotypic IQ, hence an estimate of constancy can suffice as a proxy.

2.2.2. Estimating historical changes in Flynn effect rates

The Flynn effect has been associated with a gain of approximately three points per decade amongst developed countries over the course of the 20th century (Flynn, 1987, 2009a). Some researchers have estimated higher gains of around five–seven points per decade on certain tests such as the Raven's Matrices (Dickens & Flynn, 2001). Whilst the Flynn effect is often described as having started after the Second World War in developed countries, some evidence suggests that it may have been occurring in the early decades of the 20th century, and possibly even in the last decades of the 19th century (Cattell, 1950; Finch, 1946; Neisser, 1997; Maxwell, 1954; Raven, 2000; Tuddenham, 1948). Neisser (1997) for example has argued that American children in 1932 would have obtained IQs of about 80 on tests normed in 1997; one problem with this however is the assumption of constancy in extrapolating historical rates of gains due to the Flynn effect. Jensen (1998) illustrates the problematic nature of this with the observation that, if Aristotle's IQ were representative of the IQs of ancient Athenians, then he would absurdly score somewhere in the region of −1000, assuming that the current rate of gain holds constant throughout history. Thus far only the little known studies of Crepin (2009a, b) have attempted to derive reasonable historical estimates of Flynn effect gains. In his studies, Crepin argues that the rate of change in secular gains could not have been constant throughout history, and that there must have been a cut-off point associated with a lower limit IQ. He argues that this cut-off point was around 50, and that the Flynn effect must have started off slowly for many centuries prior to accelerating after the advent of European modernity (which Crepin designates as having occurred after 1870), with the biggest gains having occurred during the 20th century. Meisenberg, Lawless, Lambert, and Newton (2005) anticipated Crepin's argument that gains would have been relatively small in the centuries leading up to the 20th, and have argued that the true shape of the historical curve of the Flynn effect is sigmoidal, with the effect having come to an end amongst European and American cohorts born after 1980. Crepin's estimates are somewhat speculative and unrealistic (he suggests that the Western IQ mean in 1952 would have been 69 for example). Despite this, the assumptions undergirding them are reasonable. The sorts of factors that likely initially influenced the Flynn effect (such as good nutrition and adequate hygiene) were not widespread prior to 1900. Furthermore, the “educational revolution” (mass expansion of the educational system) didn't occur until after the Second World War (Goldin & Katz, 1999; Meyer, Ramirez, Rubinson, & Boli-Bennett, 1977; Meyer, Ramirez, & Soysal, 1992; Schofer & Meyer, 2005). In preference to Crepin's estimates, new estimates are created for the 20th century based on the assumption that IQ rose by 3 points a decade until 2000, at which point it ceased. Thus the 1900 IQ is set at 70. Crepin's pre-20th century estimates are more reasonable, for example people living during the renaissance could realistically have exhibited IQs of around 60 relative to people living today. It must be noted however that simulations indicate that the genotypic IQ of people living in the 15th century was probably only a couple of points lower than today (Hart, 2007). One way to make sense of this apparent contradiction is to return to the idea that Flynn effect gains do not occur on *g*; Crepin's estimates are reasonable if they concern changes in the development of some specific modernity-salient subfactor (such as fluid cognitive ability [Blair, 2006]), which, relative to today, would have been significantly underdeveloped amongst people living in the 15th century.

As with changes in genotypic IQ, Flynn effect gains employing this “pastiche” variable are calculated at decadal intervals utilizing the slope of the gradient between each time point.

Table 2
Decadal scores for each variable used.

Year	Innovation rate (events/year/ billion people)	Genotypic IQ (Nyborg dysgenesis estimates)	Genotypic IQ (Meisenberg dysgenesis estimates)	Flynn effect estimates	GDP (PPP) per capita (1990 international dollars)	Homicide rates (per 100,000)	Male literacy (% literate)
1455	5.50	96.95	96.95	57.50	764.43	49.50	
1465	2.00	97.28	97.15	57.77	771.89	44.04	
1475	4.50	97.60	97.35	58.05	779.35	38.58	
1485	3.00	97.93	97.55	58.32	786.81	33.12	
1495	7.50	98.25	97.76	58.60	794.27	27.66	
1505	5.00	98.58	97.96	58.87	803.45	22.20	10.00
1515	4.00	98.90	98.16	59.15	814.35	21.56	11.30
1525	3.00	99.23	98.36	59.42	825.25	20.93	12.60
1535	4.50	99.55	98.56	59.70	836.15	20.29	13.90
1545	6.50	99.88	98.76	59.97	847.05	19.66	15.20
1555	5.00	100.20	98.96	60.25	857.95	19.02	16.50
1565	3.50	100.53	99.16	60.52	868.85	18.38	17.80
1575	5.00	100.85	99.37	60.80	879.75	17.75	19.10
1585	6.50	101.18	99.57	61.07	890.65	17.11	20.40
1595	5.50	101.50	99.77	61.35	901.55	16.48	21.70
1605	7.50	101.83	99.97	61.62	913.25	15.84	23.00
1615	8.00	102.15	100.17	61.90	925.75	14.67	25.33
1625	7.00	102.48	100.37	62.17	938.25	13.51	27.66
1635	7.00	102.80	100.57	62.45	950.75	12.34	29.99
1645	5.50	103.13	100.77	62.72	963.25	11.17	32.32
1655	8.00	103.45	100.98	62.99	975.75	10.01	34.65
1665	16.00	103.78	101.18	63.27	988.25	8.84	36.98
1675	14.00	104.10	101.38	63.54	1000.75	7.67	39.31
1685	7.50	104.43	101.58	63.82	1013.25	6.50	41.64
1695	6.50	104.75	101.78	64.09	1025.75	5.34	43.97
1705	9.00	105.08	101.98	64.37	1040.79	5.34	46.3
1715	9.50	105.40	102.18	64.64	1058.37	3.31	49.34
1725	8.50	105.73	102.38	64.92	1075.95	5.28	52.38
1735	11.50	106.05	102.59	65.19	1093.53	5.25	55.42
1745	12.00	106.38	102.79	65.47	1111.11	5.22	58.46
1755	11.00	106.70	102.99	65.74	1128.69	5.19	61.50
1765	12.50	107.03	103.19	66.02	1146.27	5.16	63.20
1775	15.50	107.35	103.39	66.29	1163.85	5.13	64.90
1785	16.50	107.68	103.59	66.57	1181.43	5.10	66.60
1795	15.50	108.00	103.79	66.84	1199.01	5.07	68.30
1805	16.00	108.33	103.99	67.12	1216.59	5.04	70.00
1815	12.50	108.65	104.20	67.39	1234.17	4.74	69.60
1825	16.00	108.98	104.40	67.67	1327.40	4.44	69.20
1835	17.00	109.30	104.60	67.94	1496.20	4.14	68.80
1845	20.00	109.63	104.80	68.21	1665.00	3.84	68.40
1855	16.50	109.52	105.00	68.49	1833.80	3.58	68.00
1865	15.50	108.95	104.67	68.76	2002.60	2.91	70.43
1875	14.00	108.38	104.34	69.04	2273.16	2.28	72.87
1885	18.50	107.81	104.01	69.31	2645.46	2.13	75.30
1895	16.00	107.24	103.68	69.59	3017.76	1.99	77.74
1905	17.00	106.67	103.35	71.50	3390.06	1.84	80.17
1915	12.50	106.10	103.02	74.50	3862.46	1.59	81.98
1925	13.50	105.53	102.69	77.50	4221.96	1.34	83.80
1935	14.00	104.96	102.36	80.50	4581.46	1.17	85.61
1945	10.50	104.40	102.03	83.50	4940.96	0.99	87.42
1955	14.00	103.83	101.7	86.50	6569.96	0.82	89.24
1965	13.50	103.26	101.37	89.50	9673.86	1.06	91.05
1975	9.50	102.69	101.04	92.50	13,563.65	1.30	92.86
1985	8.50	101.98	100.71	95.50	16,376.95	1.22	94.67
1995	7.00	101.19	100.38	98.50	19,190.25	1.14	96.49
2005	5.50	100.40	100	100.00	22,003.55	1.06	98.30

2.2.3. Additional variables

Three variables were chosen on the basis that a) they might significantly influence innovation rates and also the Flynn effect, and b) data were available spanning from the Middle Ages to the present day. The first variable is homicide rates (measured in homicides per 100,000), which have been declining in Europe since the Middle Ages. It has been argued that the decline in homicide rates reflects a transition towards greater self-control, which was essential for the process of modernization (Eisner, 2001). The data (which come from Eisner, 2001) are available for a representative sample of European countries including England, the Netherlands and Belgium, the Scandinavian countries, Germany, Switzerland and Italy. These data are available from the 13th century to the end of the 20th. More recent homicide rate data were available from the United Nations Office on Drugs & Crime, 2010.

Table 3
Correlation matrix for all variables used ($N = 51$ decades).

	Innovation rates	Genotypic IQ (Nyborg dysgenesis estimates)	Homicide rates	Literacy rates	Genotypic IQ (Meisenberg dysgenesis estimates)	Flynn effect	GDP (PPP) per capita
Innovation rates	1						
Genotypic IQ (Nyborg dysgenesis estimates)	.860**	1					
Homicide rates	−.692**	−.710**	1				
Literacy rates	.633**	.571**	−.944**	1			
Genotypic IQ (Meisenberg dysgenesis estimates)	.875**	.992**	−.780**	.662**	1		
Flynn effect	.183	.030	−.672**	.824**	.144	1	
GDP (PPP) per capita	−.065	−.209	−.448**	.624**	−.099	.930**	1

** $P \leq .01$.

The second variable is male literacy rates, which have been increasing from the 1500s onwards in Europe, and may significantly influence innovation rates owing to the fact that a more literate population is better able to both disseminate ideas and draw inspiration from the writings of others. A time-course of these was obtained from Mitch (1992), who computes literacy means for England, Scotland, Ireland, France, Sweden, Iceland, Holland, Austria, Italy, Spain, Portugal and Greece. These data are somewhat incomplete owing to the paucity of literacy data from centuries ago; however, the numbers can be considered representative of European literacy means in previous centuries as they indicate a secular increase. These data were available in a satisfactorily representative form up until 1900. Another limitation of this dataset was that literacy estimates were not included for the period 1455–1499. This resulted in five missing cases that had to be treated as missing data. The data from Mitch (1992) were supplemented with 2005 data on literacy rates from the United Nations (2006), obtained for all of the countries used.

The third variable is historical estimates of wealth as measured by GDP (PPP) per capita in 1990 international dollars, which are available from Maddison (2007) for a representative average of 12 European countries. Increased wealth may have encouraged innovation through the provision of incentives to innovate.

As with the IQ measures, decadal increments for these measures were derived from the gradient of the slope between each year for which data were available.

A complete list of the variables used is presented in Table 2.

3. Results

3.1. Correlations and multiple regression

A correlation matrix was computed using SPSS for all variables. Post 2005 scores were excluded for the IQ and innovation measures. This also makes the correlations more conservative as future projections are by definition speculative. Missing data were handled using list-wise deletion.

Table 3 indicates that both genotypic IQ estimates using Nyborg's and Meisenberg's post-1850 dysgenesis rates correlate very strongly (.992). Whilst both genotypic IQ measures correlate strongly with innovation rates (.860 and .875), the Flynn effect is non-significantly correlated with this variable (.183). The Flynn effect correlates strongly with both literacy (.824) and homicide rates (−.672). The strongest correlate of the Flynn effect is GDP (PPP) per capita (.930). Homicide and literacy rates appear to also correlate quite strongly with the Flynn effect. They are also strong predictors of innovation

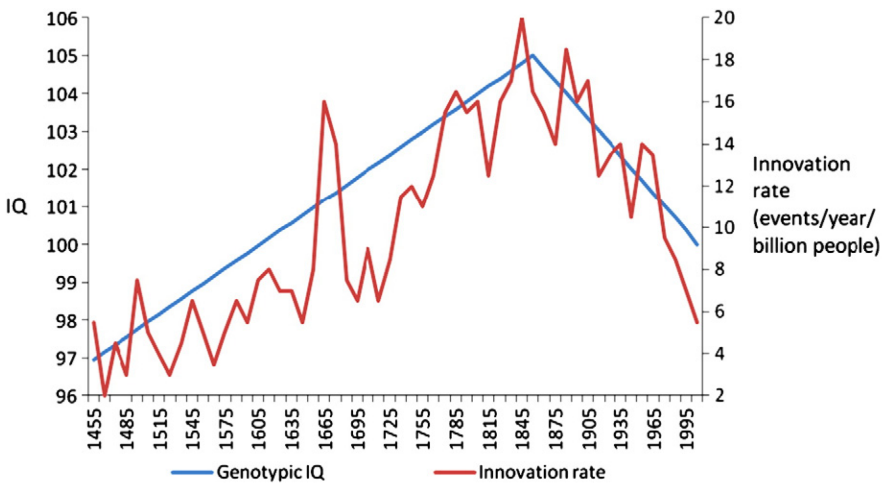

Fig. 1. Two-axis graph illustrating the relationship between change in genotypic IQ (using Meisenberg's dysgenesis rate estimates) and innovation rate over time ($r = .876$, $N = 56$ decades, $P < .01$). Nyborg's dysgenesis rate estimates (not shown) correlated at $r = .866$, $N = 56$ decades, $P < .01$.

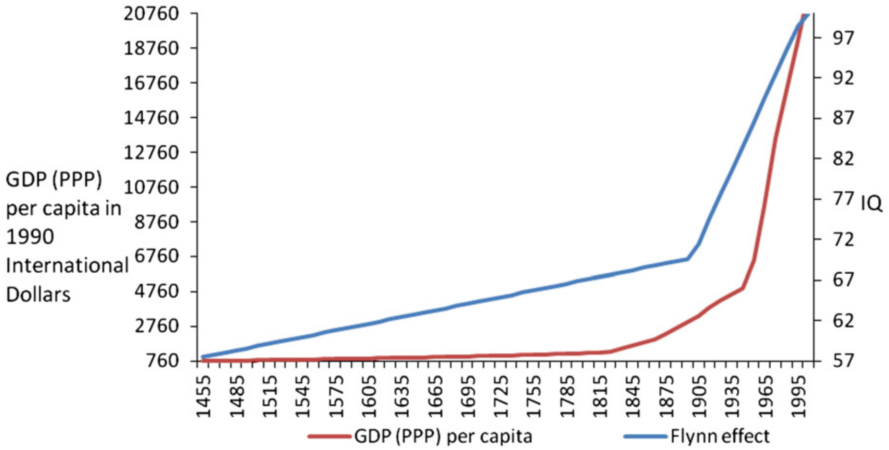

Fig. 2. Two-axis graph illustrating the relationship between historical Flynn effect estimates and Maddison's historical GDP (PPP) per capita data ($r = .93$, $N = 57$ decades, $P \leq .01$).

rates (−.692 and .633 respectively), and they appear also to strongly correlate with each other (−.944).

Fig. 1 indicates that the relationship between changes in genotypic IQ and innovation rate becomes even stronger when the five missing cases are incorporated. Fig. 2 indicates that the biggest growth in both GDP (PPP) per capita and the Flynn effect occurred during the 20th century. Fig. 3 indicates the negative relationship between illiteracy and homicide rates and the Flynn effect.

Table 6 presents the results of regression analyses in which innovation rates are predicted with both genotypic IQ estimates alternatively along with a composite factor comprised of illiteracy and homicide rates and another comprised of the historical Flynn effect rate estimates along with GDP (PPP) per capita. In both cases these common factors were created so as to avoid problems associated with multicollinearity. In this model, despite the aforementioned dimension reduction, there was still a problem with multicollinearity (variance inflation factors were above 10 (Kutner, Nachtsheim, Neter, & Li, 2005)), with the composite illiteracy/homicide rate variable exhibiting the largest VIF in both cases. Removing this variable substantively reduced the multicollinearity between the remaining variables and had only a modest impact on the fit of the models.

Table 7 presents the results of a second set of regression analyses in which the common factor of the Flynn effect and GDP (PPP) per capita was used as the dependent variable. In these models the strongest predictor was the composite illiteracy/homicide rate variable ($\beta = -1.251$ and -1.389 respectively), with acceptable levels of multicollinearity (all VIFs were below 6). Both the Nyborg and Meisenberg genotypic IQ estimates became *significant negative predictors* of the Flynn effect/GDP (PPP) per capita variable ($\beta = -.894$ and $-.978$ respectively). Innovation rates were non-significant predictors.

3.2. Temporal autocorrelation

Temporal autocorrelation results from the non-independence of data points due to proximity in time. This has the potential to significantly inflate the relationships between variables in temporal analysis. A two-stage control for temporal autocorrelation was devised in which initially the data were broken down and dummy coded based on 90 year periods (1505–1595, 1605–1695, 1705–1795, 1805–1895 and 1905-1995), and correlation analysis was preformed within each period to determine sign stability.

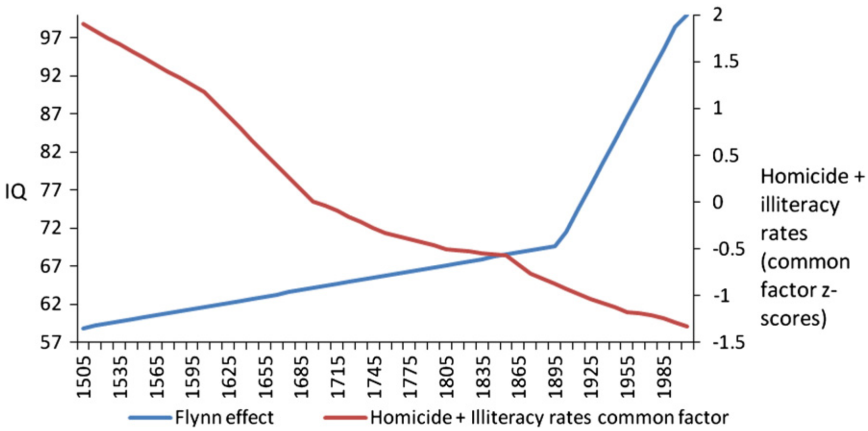

Fig. 3. Two-axis graph illustrating the decline in the common factor amongst homicide/illiteracy rates and Flynn effect ($r = -.661$, $N = 51$ decades, $P \leq .01$).

Table 4 indicates that the sign of the coefficients are in the correct direction within each of the five 90 year periods. If temporal autocorrelation were substantively obviating these relationships within time periods, the sign of the correlation coefficients would be expected to change randomly. In each case, the odds of the signs being in the correct direction five times out of five is 1 in 64.

The second stage of the control involved dummy coding the periods such that 1505–1595 = 1, 1605–1695 = 2 etc, and then regressing the genotypic IQ along with this combined time period variable against innovation rates. The correlation between the homicide + illiteracy rate common factor and combined periods is over .95, which prevents it from being used in regression analysis owing to excessive collinearity.

Table 5 reveals that using a general within period control does not substantively diminish the relationship between genotypic intelligence and innovation rates. This finding replicates when the genotypic IQ measure incorporating the Nyborg dysgenesis estimates are used ($\beta = .805$, $P < .01$).

It needs to be noted that whilst these results indicate that the major relationships observed here are at least somewhat robust to temporal autocorrelation, the analysis is nonetheless fairly crude, and more sophisticated autocorrelation controls.

3.3. Path analysis

Path analysis indicates that the structure of relationships inferred from regression analysis is robust to the use of explicit assumptions about causality (Fig. 4). High genotypic IQ promotes innovation and decreases homicide/illiteracy. It is also a substantial negative predictor of the Flynn effect, which lends credence to the idea that dysgenesis and the Flynn effect operate on mutually exclusive sources of variance in measures of intelligence, which are essentially free to covary. The Flynn effect significantly promotes wealth, and is in turn promoted by the common factor of homicide and illiteracy. This common factor is also a significant independent predictor of wealth. The Flynn effect is also a positive predictor of innovation rates. This model was substantively replicated using the genotypic IQ estimates incorporating Meisenberg's dysgenesis rates ($\chi^2 = 4.5$, df = 3, RMSEA = .1, $N = 51$ decades).

Table 4
The results of analyses in which each variable (genotypic IQ and the homicide + illiteracy common factor) were independently correlated with innovation rates and the Flynn effect + GDP (PPP) per capita common factor respectively within each of the 90 year periods. Due to the small N (10) in each case significance levels are omitted.

	1505–1595 (r)	1605–1695 (r)	1705–1795 (r)	1805–1895 (r)	1905–1995 (r)
Genotypic IQ (Meisenberg estimates) predicting innovation rates	.437	.278	.923	.244	.819
Homicide + illiteracy common factor predicting Flynn effect + GDP (PPP) per capita common factor	-1	-1	-.992	-.974	-.934

Table 5
The results of regression analysis in which genotypic IQ along with combined time periods, are used to predict innovation rates ($N = 50$ decades).

	β (Predicting innovation rates)
Genotypic IQ (Meisenberg estimates)	.778**
Combined time periods	.140

** $P < .01$.

4. Discussion

4.1. Science in decline

What are the consequences of changing levels of genotypic IQ? The data indicate that this variable is the strongest predictor of changes in the rates of scientific and technological innovation. Whilst a genotypic IQ decline of between 1 and 2 points a generation does not seem large, it is important to stress the impact that such a change can have on the frequencies of those with the highest levels of IQ. A 105–109 point decline in the Western genotypic IQ mean would have decreased the proportion of the population with the sort of IQ needed for significant innovation (i.e. ≥135) by ~55–75% percent. The worldwide increase in the rate of innovation from 1455 to 1873 followed by a sharp decline is consistent not only with continued dysgenesis in the West since the latter half of the 19th century, but also with the existence of a "eugenic phase" in the population cycle (Weiss, 2008). During this phase genotypic intelligence was rising and innovators were becoming more common on a per capita basis, congruent with positive directional selection for 'bourgeois' traits.

It must be noted that total numbers of innovations are not as strongly related to genotypic IQ as are innovation rates ($r = .512$, $p < .01$, $N = 55$). Total numbers of innovations (which based on Bunch and Hellemans [2004] appear to have peaked in the 1960's) relate more strongly to the size of the most innovative populations. This relationship suggests that bigger populations contain more innovators, however dysgenesis is essentially 'diluting' the impact of innovators, such that per capita innovative capacity declines with the passage of time. This process should be apparent in the ways in which science is organized in the modern world. For example, if relative to the population as a whole high intelligence individuals are becoming scarcer, established scientists might have to resort to recruiting individuals of more mediocre ability. This might explain the tendency for contemporary scientists, more so than scientists of earlier generations, to select for conscientious and sociable workers as high conscientiousness does not require high IQ (Charlton, 2008). Consistent with Charlton's (2008) argument, it has been found that whilst the size of scientific teams has been increasing, the relative impact of individual scientists has been decreasing (Jones, 2009; Wuchty, Jones, & Uzzi, 2007). This process suggests a quality vs. quantity trade-off where science is increasingly organized around those with lower genotypic IQs and lower innovative potential, who are in turn increasingly reliant upon larger teams for accomplishment.

It is important to note that whilst it is likely that dysgenesis has played a substantial role in reducing innovation rates, other factors might be at play also. For example, in

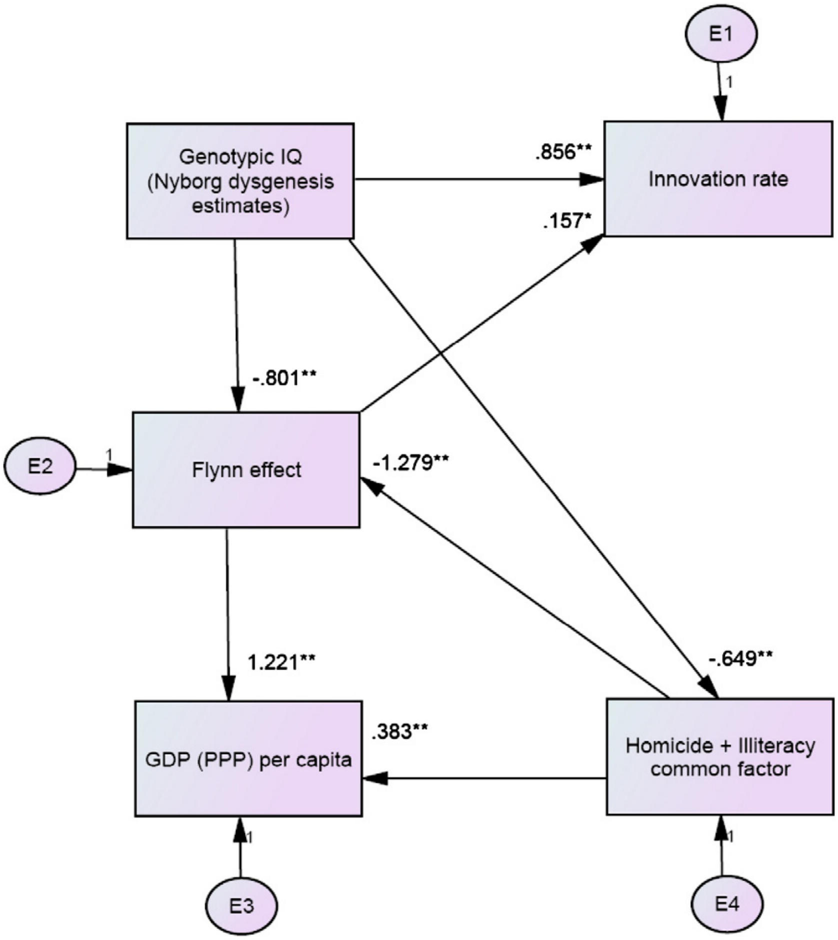

Fig. 4. Path model in which the genotypic IQ estimates incorporating Nyborg's dysgenesis rates are used to predict innovation rates, the Flynn effect, and the common factor of homicide and illiteracy rates. The model fit is reasonable ($\chi^2=3.8$, df = 3, RMSEA = .07, $N=51$ decades). *$P<.05$, **$P<.01$.

some areas of research, discovery and innovation might be hitting physical limits as the "low hanging fruit" (discoveries such as new bodily organs, stable chemical elements, planets in the solar system and large mammalian species) have mostly all been "picked", so to speak. What typically remains to be discovered is smaller and requires significantly greater effort to find (Arbesman, 2011; Horgan, 1997). It is possible therefore that in some fields there are simply fewer innovations and discoveries to be made in the modern era than there were in previous eras, which might account for the paucity of modern innovation rates in some domains, independently of declining genotypic IQ.

Economic limits are also important, as whilst it may physically be feasible to develop a novel technology (such as building a manned spaceship that could travel to Mars), it may not be so economically. Hence economic limits may inhibit innovation (Cowen, 2011; Huebner, 2005a).

The location of both physical and economic limits may also be partially dependent upon genotypic IQ however, as whilst smaller and rarer things may simply be harder to

Table 6
Prediction of innovation rates with two regression analyses using both estimates of genotypic IQ change, along with two common factors: Flynn effect gains with GDP (PPP) per capita, and literacy with homicide rates. Missing data was handled using list-wise deletion in SPSS ($N=51$ decades).

Variable	β	β (removal of the literacy/ homicide rate common factor)	Variable	β	β (removal of the literacy/ homicide rate common factor)
Genotypic IQ (Nyborg dysgenesis estimates)	.706**	.873**	Genotypic IQ (Meisenberg dysgenesis estimates)	.787**	.874**
Common factor (Flynn effect + GDP [PPP] per capita)	−.030	.140	Common factor (Flynn effect + GDP [PPP] per capita)	−.039	.040
Common factor (illiteracy and homicide rates)	−.233	–	Common factor (illiteracy and homicide rates)	−.122	–
Model fit (adjusted R^2)	.75	.75	Model fit (adjusted R^2)	.75	.76

** $P\leq.01$.

Table 7
Two regression analyses predicting a composite variable measuring gains due to the Flynn effect along with GDP (PPP) per capita. Predictors include genotypic IQ estimates, innovation rates, and the common factor of illiteracy and homicide rates. Missing data was handled using list-wise deletion in SPSS ($N=51$ decades).

Variable (regression 1)	β	Variable (regression 2)	β
Genotypic IQ (Nyborg dysgenesis estimates)	−.894**	Genotypic IQ (Meisenberg dysgenesis estimates)	−.978**
Innovation rates	−.011	Innovation rates	−.017
Common factor (illiteracy and homicide rates)	−1.251**	Common factor (illiteracy and homicide rates)	−1.389**
Model fit (adjusted R^2)	.90	Model fit (adjusted R^2)	.89

** $P\leq.01$.

discover, it is still the case that higher IQ people are more likely to make such discoveries, as *g* becomes increasingly important to life-outcomes as a function of the relative difficulty of a task (e.g. Gordon, 1997; Gottfredson, 1997b). It goes without saying, however, that whilst *g* might help overcome apparent physical limits in some cases, it cannot do so in cases where physical limits are dependent on physical laws, i.e. no matter how smart people are they will never build a working perpetual motion machine. Economic limits must rely to an extent on the efficiency of technology, which in turn would be dependent upon the genotypic IQ of innovators. For example if a way were found to manufacture cheap and reliable nuclear rockets, then manned spaceflight to Mars would not seem nearly as daunting from an economic perspective as it does currently.

A third possibility is that there have been significant cultural changes over the last 160 years that might have influenced innovation rates. According to Murray (2003), many accomplished scientists in the 19th century and earlier subscribed to Thomism — the doctrine that one can develop an appreciation for God by acquiring knowledge of creation. For scientists under the influence of Thomism, scientific research was a sacred activity, to be pursued with the energy and focus that religion inspires. But Thomism requires a sophisticated conception of religion: comprehension of which likely requires a fairly high degree of genotypic intelligence (Cofnas, 2012). As intelligence decreases, so too does the ability to hold the sorts of complex theological notions that would engender a Thomistic attitude. There is a potentially negative feedback here: as genotypic intelligence decreases, so does the ability (and tendency) to hold those kinds of religious beliefs that encourage Thomism. Decreases in both genotypic intelligence and Thomism could therefore have taken a joint toll on innovation rates.

Huebner's (2005a) finding of declining innovation rates has not been received uncritically, least of all by singularitarians, whose prognostications would appear to be dependent not only on increasing absolute numbers of innovations but also on increasing rates of innovation. For example, Smart (2005), in his response to Huebner, suggests that much technological innovation takes place below the level of human perception, such that it is not captured by "subjective" measures of innovation of a sort that require the innovation to be sufficiently conspicuous to be noticed by the investigator. Smart suggests that rates of "technology initiated" as opposed to "human initiated" innovation may well be subject to accelerating returns when measured objectively, and presents Moore's law (the exponential increase in the cost effectiveness of computing power) as one such example. The key issue here is human perception. It could be argued that the need for humans to be able to perceive a scientific or technological event as an innovation is both a necessary and a sufficient criterion for the definition of innovation, as it suggests that a threshold of substantive novelty has to be passed. Scientific and technological progress of a sort that fails to pass this threshold of notability and therefore fails to find itself listed in inventories is unlikely to constitute an innovation in the sense in which Huebner uses the term, as such developments lack sufficient novelty and are more likely to be incremental refinements on existing technologies (microinnovations) rather than substantially novel developments in and of themselves (macroinnovations). As long as this subjective criterion is applied consistently across inventories, then there exists inter-rater reliability, as evidenced by the fact that both Murray's and Gary's innovation rate data correlate highly with Huebner's. Also relevant here is Huebner's observation that inventories typically also contain some microinnovations, and that their exclusion would in point of fact potentiate the apparent decline in innovation rates.

4.2. Wealth in ascent

The inferred growth pattern of historical Flynn effect gains seems to strongly parallel the growth in GDP (PPP) per capita (Fig. 2). The common factor of these two variables is strongly predicted by the combined influence of decreasing illiteracy and homicide rates, and path analysis indicates a reasonable fit to models in which this factor is assumed to promote the Flynn effect. These patterns are consistent with the life history model of the Flynn effect, as education is known to decelerate the life history speeds of individuals such as in the case of the well-established literacy-fertility relationship in women (Grossman, 1972). Declining homicide rates are also likely in part a consequence of slowing life history, as higher-*K* individuals tend to be less impulsive and more controlled owing to their possessing a better capacity for forward planning (Figueredo et al., 2006). The historical homicide rates literature acknowledges a significant contribution from increasing education in reducing these rates over time (Eisner, 2001); furthermore homicide and male education are significantly and robustly negatively correlated at ecological scales (Cole & Gramajo, 2009). Additionally Clark (2007) connects decreasing homicide rates and increasing literacy rates with selection for more "bourgeois" orientations from the Middle Ages to the early 19th century, which are associated with longer time preferences and other slow life history characteristics (Figueredo, 2009). This suggests that up to the early 19th century, genetic selection was the primary mechanism through which life history slowed, however during the 'the onset of the demographic transition' in the 19th century, developmental plasticity was the principal driver of this and related tendencies such as the Flynn effect. Other developmentally relevant factors not captured by this model would include changes in the impact of infectious diseases and malnutrition, the mitigation of which would have contributed to slowing the life history speeds of populations (Woodley, 2011a, in press).

The association of the historical Flynn effect estimates with GDP (PPP) per capita, coupled with the apparent independence of the latter and weak association of the former with innovation rates suggests that since the middle of the 19th century growth in individual wealth has not been substantively dependent on an increasing rate of innovation. Perhaps it is the case that runaway wealth generation is more strongly dependent on the ways in which pre-existing technologies are used, such that simply reworking an existing technology (i.e. generating microinnovation) produces more in the way of immediate returns than actually having to develop a fundamentally new technology (which is hard and evidently getting harder for populations, not to mention risky) (Cowen, 2011). This is compatible with the idea that the Flynn effect has been associated with a low risk strategy favoring the development and proliferation of cognitive specialization (such as microinnovating skills), as by allowing the carrying capacity of Western nations to increase via more sophisticated divisions of cognitive labor, larger and also wealthier populations would have ensued owing to enhanced aggregate economic efficiency (Woodley, 2011b).

It should be noted that Flynn effect gains and innovation rates were not wholly independent in path analysis, as there existed a small magnitude but significant path between the two. This could be accounted for by Huebner's observation that Bunch and Hellemans (2004) compilation appeared to contain the sorts of microinnovation that in turn might be promoted by the Flynn effect.

5. Conclusions

What then is the most likely future scenario for science and technology? As was discussed, the decline in genotypic intelligence does not seem to have affected the rate at which wealth has been increasing in Western nations. This observation bodes especially well for the peoples of developing nations as despite the possibility that they possess lower levels of genotypic intelligence than Western populations (Lynn, 2006), it is indicated that the Flynn effect hasn't really started to take off in these nations, but that it has the potential to do so (Wicherts, Dolan, Carlson, & van der Maas, 2010). This is evidenced by observations of a nascent Flynn effect in South Africa (te Nijenhuis, Murphy, & van Eeden, 2011), Kenya (Daley, Whaley, Sigman, Espinosa, & Neumann, 2003), Dominica (Meisenberg et al., 2005), Saudi Arabia (Batterjee, 2011) and elsewhere. It is entirely possible therefore that many of the less developed nations are entering into the early stages of an "enhanced growth" phase in the Flynn effect, a consequence of which might be significant decreases in poverty, such as is currently occurring in Africa (Sala-i-Martin & Pinkovskiy, 2010).

The factors which have made this possible would include the rise of generalized education, large scale vaccination, nutritional enhancements and contraceptives all of which have the potential to encourage life history speed deceleration and wealth accumulation (Woodley, 2011a, in press). Another significant input is Western innovations such as information technology, vehicles, infrastructure, etc., which function as a basic substrate upon which wealth generating and carrying capacity enhancing refinements (i.e. microinnovations) can be made.

Amongst Western nations genotypic intelligence has been in steady decline since at least 1850, (the first beginnings of the demographic transition), and is projected to decline even more rapidly into the 21st century (Lynn & Harvey, 2008; Meisenberg, 2009, 2010; Meisenberg & Kaul, 2010; Nyborg, in press). Whilst the decline in genotypic IQ has not negatively impacted the growth in wealth, it is clearly impacting progress in science as measured by declining innovation rates. With a decline in scientific progress populations become less able to counter potential existential risks (e.g., detecting/stopping a large asteroid headed towards Earth, coping with depleting fossil fuels etc.). Another hazard is that in the absence of a "critical mass" of sufficiently intelligent individuals engendering an appropriate level of scientific rigor, "junk science" has the potential to proliferate to an extent never before seen in free nations (cf. Cofnas, 2012). This has the potential to directly negatively impact individuals via worsening medical research and worsening political policy.

The act of sustaining a sophisticated macroinnovation base is itself a highly g-loaded task (Itzkoff, 2003); general technological regression (the replacement of existing innovations with lower quality 'surrogates') is therefore likely to become increasingly prevalent. Indeed there exists historical precedent for this, as the dark ages that succeeded the collapse of the Roman empire (~ 476 CE) and earlier, Mycenaean Greek civilization (~ 1200 BCE), were in both instances characterized by plummeting innovation rates and the loss of innovations (Huebner, 2006). It is possible that these earlier collapses were also driven by dysgenesis (Weiss, 2008).

This trend may also couple with the anti-Flynn effect, which has been observed in a number of Western nations over the last couple of decades, and is characterized by significant losses in phenotypic IQ (Flynn, 2009b; Shayer & Ginsburg, 2009; Sundet, Barlaug, & Torjussen, 2004; Teasdale & Owen, 2008). One possibility is that this is linked with the transition towards faster life histories (as evidenced by higher total fertility), which has been observed in the most developed nations (Myrskylä, Kohler, & Billari, 2009). If the anti-Flynn effect is being driven by accelerated life history speed,[2] then it will be associated with a decline in wealth accumulation orientation, an increase in violence and a tendency towards avoiding education, optimum levels of which are dependent on slow life history (Figueredo et al., 2006; Giosan, 2006). The combined impact of

[2] One possible cause of this 'anti-demographic transition' is that dysgenesis may be triggering macro-social feedback loops that are producing life history acceleration cues. These could operate via social instability resulting from inefficacious foreign and domestic policy (i.e. prolonged police actions in foreign countries, protracted economic instability, diminishing educational standards etc). Significant acts of violence (such as those resulting from terrorist attacks) and natural disasters (such as earthquakes) have also been shown to raise fertility (e.g. Rodgers, St John and Coleman, 2005), another possibility therefore is that increasing awareness of such occurrences (due to enhanced media) has amplified their mortality salience, which has had an attendant accelerating effect on life history speed.

Please cite this article as: Woodley, M.A., The social and scientific temporal correlates of genotypic intelligence and the Flynn effect, *Intelligence* (2012), doi:10.1016/j.intell.2011.12.002

these two factors would be to significantly reduce the level of development and standard of living in the West over the course of the next 100 years or so.

Based on these findings, it would appear that a singularity of sorts might already have happened in the economic sense, as there has been an explosion in the growth of wealth amongst Western countries since the 1800s, and this also has the potential to happen to some extent in many developing countries. The singularity in the technological sense is unlikely to happen however, owing to the apparently significant relationship between changes in the level of genotypic intelligence and innovation rates, both of which have been declining sharply over the course of the last 130 + years.

Some futurologists see genetic and reproductive engineering for enhanced cognition as desirable, and even recognize dysgenesis as a potential existential risk (Bostrom, 2002). Huebner (2005a) even speculates that limitations in the efficiency of the human brain might be behind declining innovation rates and that genetic engineering for higher intelligence may be a solution to the problem. The idea of using reproductive engineering to mitigate dysgenesis in human populations is not a new one (see: Lynn, 2001; Agar, 2004; Glad, 2006). Technologies like gamete cloning, when mature enough, may permit individuals to select for IQ enhancing alleles, but would only realistically be able to raise the IQ of offspring by a point or two at best (Lee, 2010). Successful mapping of the genes for IQ coupled with long-term use of these technologies might reduce the impact of dysgenesis; however, there is no guarantee that the future Western political climate and regulatory frameworks will be sufficiently libertarian so as to permit this kind of research and its commercialization. A practical alternative to reproductive engineering might be to find ways of safe guarding knowledge. If there exists a population long-wave cycle in eugenic and dysgenic fertility patterns, such as has been predicted to exist by Weiss (2008) cf. Itzkoff (2003), and earlier by Spengler (1918, 1923/1991), then such efforts may prove useful to technologically ascendant civilizations in the future. Absent such an endeavor, vital scientific knowledge may become lost to humanity as populations worldwide move towards a post-scientific state in completing the dysgenic phase of the population cycle.

Acknowledgment

I would like to acknowledge Nathan Cofnas, James Flynn and two anonymous reviewers for comments that substantively improved this manuscript.

References

Agar, N. (2004). *Liberal eugenics: In defence of human enhancement.* London: Blackwell Publishing.

Arbesman, S. (2011). Quantifying the ease of scientific discovery. *Scientometrics*, *86*, 245–250.

Asimov, I. (1994). *Asimov's chronology of science and discovery: How science has shaped the world.* New York: Harper Collins.

Batterjee, A. (2011). Intelligence and education: the Saudi case. *Mankind Quarterly*, *52*, 133–190.

Blair, C. (2006). How similar are fluid cognition and general intelligence? A developmental neuroscience perspective on fluid cognition as an aspect of human cognitive ability. *The Behavioral and Brain Sciences*, *29*, 109–160.

Bostrom, N. (2002). Existential risks: Analyzing human extinction scenarios and related hazards. *Journal of Evolution & Technology*, 9http://www.jetpress.org/volume9/risks.html

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

Brand, C. R. (1990). A 'gross' underestimate of a 'massive' IQ rise? A rejoinder to Flynn. *Irish Journal of Psychology*, *11*, 52–56.

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.

Bunch, B., & Hellemans, A. (2004). *The History of Science and Technology: A Browser's Guide to the Great Discoveries, Inventions, and the People Who Made Them from the Dawn of Time to Today.* New York: Houghton Mifflin Company.

Cattell, R. B. (1936). Is our national intelligence declining? *The Eugenics Review*, *28*, 181–203.

Cattell, R. B. (1937). *The fight for our national intelligence.* London: King & Sons.

Cattell, R. B. (1950). The fate of national intelligence: Test of a thirteen-year prediction. *The Eugenics Review*, *42*, 136–148.

Cattell, R. B. (1974). Differential fertility and normal selection for IQ: Some required conditions in their investigation. *Social Biology*, *21*, 168–177.

Charlton, B. G. (2008). Why are modern scientists so dull? How science selects for perseverance and sociability at the expense of intelligence and creativity. *Medical Hypotheses*, *72*, 237–243.

Clark, G. (2007). *A farewell to alms: A short economic history of the world.* Princeton: Princeton University Press.

Clark, G., & Hamilton, G. (2006). Survival of the richest: the Malthusian mechanism in pre-industrial England. *The Journal of Economic History*, *66*, 707–736.

Coates, J. (2005). Looking ahead: A visible end to innovation? I think not. *Research Technology Management.* Available from: josephcoates.com/pdf_files/282_An_End_to_Innovation.pdf (accessed on 28/12/11).

Cocodia, E. A., Kim, J. -S., Shin, H. -S., Kim, J. -W., Ee, J., Wee, M. S. W., et al. (2003). Evidence that rising population intelligence is impacting in formal education. *Personality and Individual Differences*, *35*, 797–810.

Cofnas, N. (2012). *Reptiles with a conscience: The co-evolution of religious and morale doctrine.* London: Ulster Institute for Social Research.

Cole, J. H., & Gramajo, A. M. (2009). Homicide rates in a cross-section of countries: Evidence and interpretations. *Population & Developmental Review*, *35*, 749–776.

Cowen, T. (2011). *The great stagnation: How America ate all the low-hanging fruit of modern history, got sick, and will (eventually) feel better.* A Penguin eSpecial from Dutton.

Crepin, H. (2009a). L'effet Flynn: ou une tentative d'analyser l' évolution de l'intelligence au cours de l'Histoire. *ComMensal*, *10*, 5–7.

Crepin, H. (2009b). La problématique sociale de l'évolution intellectuelle de nos sociétés «occidentales». *ComMensal*, *8*, 9–12.

Daley, T. C., Whaley, S. E., Sigman, M. D., Espinosa, M. P., & Neumann, C. (2003). IQ on the rise: the Flynn effect in rural Kenyan children. *Psychological Science*, *14*, 215–219.

Del Giudice, M., & Belsky, J. (2011). The development of life history strategies: Toward a multi-stage theory. In D. M. Buss, & P. H. Hawley (Eds.), *The evolution of personality and individual differences* (pp. 154–176). New York: Oxford University Press.

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

Drexler, E. (1992). *Nanosystems: Molecular machinery manufacturing and computation.* New York, NY: John Wiley and Sons.

Eisner, M. (2001). Modernization, self-control and lethal violence: The long-term dynamics of European homicide rates in theoretical perspective. *British Journal of Criminology*, *41*, 618–638.

Ellis, B. J., Figueredo, A. J., Brumbach, B. H., & Schlomer, G. L. (2009). Fundamental dimensions of environmental risk: The impact of harsh versus unpredictable environments on the evolution and development of life history strategies. *Human Nature*, *20*, 204–298.

Eppig, C., Fincher, C. L., & Thornhill, R. (2010). Parasite prevalence and the worldwide distribution of cognitive ability. *Proceedings of the Royal Society, Series B, Biological Sciences*, *277*, 3801–3808.

Falek, A. (1971). Differential fertility and intelligence: Resolution of two paradoxes and formulation of a third. *Journal of Human Evolution*, *1*, 11–15.

Figueredo, A. J. (2009). Human capital, economic development, and evolution: A review and critical comparison of Lynn & Vanhanen (2006) and Clark (2007). *Human Ethology Bulletin*, *24*, 5–8.

Figueredo, A. J., Vásquez, G., Brumbach, B. H., & Schneider, S. M. R. (2004). The heritability of life history strategy: The K-factor, covitality, and personality. *Social Biology*, *51*, 121–143.

Figueredo, A. J., Vásquez, G., Brumbach, B. H., Schneider, S. M. R., Sefcek, J. A., Tal, I. R., et al. (2006). Consillience and life history theory: From genes to brain to reproductive strategy. *Developmental Review*, *26*, 243–275.

Finch, F. H. (1946). *Enrollment increases and changes in the mental level of the high school population.* Stanford, CA: Stanford University Press.

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

Flynn, J. R. (2009a). *What is intelligence? Beyond the Flynn effect* (expanded ed.). Cambridge, UK: Cambridge University Press.

Flynn, J. R. (2009b). Requiem for nutrition as the cause of IQ gains: Raven's gains in Britain 1938–2008. *Economics and Human Biology*, *7*, 18–27.

Frost, P. (2011). Human nature or human natures? *Futures*, *43*, 740–748.

Galor, O., & Moav, O. (2002). Natural selection and the origin of economic growth. *Quarterly Journal of Economics*, *117*, 1133–1191.

Galton, F. (1869). *Hereditary genius.* London: MacMillan.

Gary, B. L. (1993). *A new timescale for placing human events, derivation of per capita rate of innovation, and a speculation on the timing of the demise of humanity.* Unpublished Manuscript.

Gelade, G. A. (2008). IQ, cultural values, and the technological achievement of nations. *Intelligence*, *36*, 711–718.

Giosan, C. (2006). High-K strategy scale: A measure of the high-K independent criterion of fitness. *Evolutionary Psychology*, *4*, 394–405.

Glad, J. (1998). A hypothetical model of IQ decline resulting from political murder and selective emigration in the former U.S.S.R.. *Mankind Quarterly*, *38*, 279–298.

Glad, J. (2006). *Future human evolution: Eugenics in the twenty-first century.* Schuylkill Haven, PA: Hermitage Publishers.

Goldin, C., & Katz, L. F. (1999). Human capital and social capital: The rise of secondary schooling in America, 1910–1940. *The Journal of Interdisciplinary History*, *29*, 683–723.

Gordon, R. (1997). Everyday life as an intelligence test: Effects of intelligence context. *Intelligence*, *24*, 203–320.

Gottfredson, L. S. (1997a). Mainstream science on intelligence: Editorial with 52 signatories, history and bibliography. *Intelligence*, *24*, 13–23.

Gottfredson, L. S. (1997b). Why *g* matters: The complexity of everyday life. *Intelligence*, *24*, 79–132.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy*, *80*, 223–255.

Hart, M. (2007). *Understanding human history: An analysis including the effects of geography and differential evolution.* Atlanta: Washington Summit Publishers.

Herrnstein, R. J., & Murray, C. (1994). *The bell curve: Intelligence and class structure in American life.* New York: Free Press Paperbacks.

Horgan, J. (1997). *The end of science: Facing the limits of knowledge in the twilight of the scientific age.* New York, NY: Broadway Books.

Howard, R. W. (1999). Preliminary real-world evidence that average human intelligence really is rising. *Intelligence*, *27*, 235–250.

Howard, R. W. (2001). Searching the real world for signs of rising population intelligence. *Personality and Individual Differences*, *30*, 1039–1058.

Huebner, J. (2005a). A possible declining trend for worldwide innovation. *Technological Forecasting and Social Change*, *72*, 980–986.

Huebner, J. (2005b). Response by the authors. *Technological Forecasting and Social Change*, *72*, 995–1000.

Huebner, J. (2006). Discussion of Coates commentary. *Technological Forecasting and Social Change*, *73*, 906–912.

Husén, T., & Tuijnman, A. (1991). The contribution of formal schooling to the increase in intellectual capital. *Educational Researcher*, *20*, 17–25.

Itzkoff, S. W. (2003). *2050: The collapse of the global techno-economy.* Ashfield, MA: Paideia.

Itzkoff, S. W. (2009). *The end of economic growth.* New York: The Edwin Mellen Press.

Jensen, A. R. (1969). How much can we boost IQ and scholastic achievement? *Harvard Educational Review*, *39*, 1–123.

Jensen, A. R. (1996). Secular trends in IQ: Additional hypothesis. In D. K. Detterman (Ed.), *The environment. Current topics in human intelligence*, *Vol. 5*. (pp. 147–150) Westport, CT: Ablex Publishing.

Jensen, A. R. (1998). *The g factor: The science of mental ability.* Westport, CT: Praeger Publishers.

Jones, B. (2009). The burden of knowledge and the "death of the renaissance man": Is innovation getting harder? *The Review of Economic Studies*, *76*, 283–317.

Juan-Espinosa, M., Cuevas, L., Escorial, S., & García, L. F. (2006). The differentiation hypothesis and the Flynn effect. *Psicothema*, *18*, 284–287.

Kane, H. D. (2000). A secular decline in Spearman's g: Evidence from the WAIS, WAIS-R and WAIS-III. *Personality and Individual Differences*, *29*, 561–566.

Kane, H. D., & Oakland, T. D. (2000). Secular declines in Spearman's g: Some evidence from the United States. *The Journal of Genetic Psychology*, *161*, 337–345.

Kurzweil, R. (2004). *The singularity is near: When humans transcend biology.* New York, NY: Viking Press.

Kutner, M., Nachtsheim, C., Neter, J., & Li, W. (2005). *Applied linear statistical models* (5th ed). Irwin, CA: McGraw-Hill.

Lee, J. J. (2010). Review of intelligence and how to get it: Why schools and cultures count, R.E. Nisbett, Norton, New York, NY (2009). ISBN: 9780393065053. *Personality and Individual Differences*, *48*, 247–255.

Lentz, T. (1927). Relation of IQ to size of family. *Journal of Educational Psychology*, *18*, 486–496.

Loehlin, J. C. (1997). Dysgenesis and IQ. *The American Psychologist*, *52*, 1236–1239.

Lubinski, D., Benbow, C. P., Webb, R. M., & Bleske-Rechek, A. (2006). Tracking exceptional human capital over two decades. *Psychological Science*, *17*, 194–199.

Lynn, R. (1989). A nutrition theory of the secular increases in intelligence—Positive correlations between height, head size and IQ. *The British Journal of Educational Psychology*, *59*, 372–377.

Lynn, R. (1996). *Dysgenics: Genetic deterioration in modern populations.* Westport, CT: Praeger.

Lynn, R. (1999). New evidence for dysgenic fertility in intelligence in the United States. *Social Biology*, *46*, 146–153.

Lynn, R. (2001). *Eugenics: A reassessment.* Westport, CT: Praeger.

Lynn, R. (2006). *Race differences in intelligence: An evolutionary analysis.* Georgia: Washington Summit Publishers.

Lynn, R. (2009). What has caused the Flynn effect? Secular increases in the development quotients of infants. *Intelligence*, *37*, 16–24.

Lynn, R. (2011). *Dysgenics: Genetic deterioration in modern populations* (Second revised edition). London: Ulster Institute for Social Research.

Lynn, R., & Cooper, C. (1993). A secular decline in Spearman's *g* in France. *Learning and Individual Differences*, *5*, 43–48.

Lynn, R., & Cooper, C. (1994). A secular decline in the strength of Spearman's *g* in Japan. *Current Psychology*, *13*, 3–9.

Lynn, R., & Harvey, J. (2008). The decline of the world's IQ. *Intelligence*, *36*, 112–120.

Lynn, R., & van Court, M. (2004). New evidence of dysgenic fertility for intelligence in the United States. *Intelligence*, *32*, 193–201.

Mace, R. (1999). Evolutionary ecology of human life history. *Animal Behavior*, *59*, 1–10.

Maddison, G. (2007). *Contours of the world economy, 1–2030 AD: Essays in macroeconomic history.* New York: Oxford University Press.

Maller, J. (1933). Vital indices and their relation to psychological and social factors. *Human Biology*, *5*, 94–121.

Maxwell, J. (1954). Intelligence, fertility and the future: A report on the 1947 Scottish Mental Survey. *Eugenics Quarterly*, *1*, 244–247.

Meisenberg, G. (2008). How universal is the negative correlation between education and fertility? *Journal of Social, Political & Economic Studies*, *33*, 205–227.

Meisenberg, G. (2009). Wealth, intelligence, politics and global fertility differentials. *Journal of Biosocial Sciences*, *41*, 519–535.

Meisenberg, G. (2010). The reproduction of intelligence. *Intelligence*, *38*, 220–230.

Meisenberg, G., & Kaul, A. (2010). Effects of sex, race, ethnicity and marital status on the relationship between intelligence and fertility. *Mankind Quarterly*, *50*, 151–187.

Meisenberg, G., Lawless, E., Lambert, E., & Newton, A. (2005). The Flynn effect in the Caribbean: Generational change of cognitive test performance in Dominica. *Mankind Quarterly*, *46*, 29–69.

Meyer, J. W., Ramirez, F. O., Rubinson, R., & Boli-Bennett, J. (1977). The world educational revolution, 1950–1970. *Sociology of Education*, *50*, 242–258.

Meyer, J. W., Ramirez, F. O., & Soysal, Y. N. (1992). World expansion of mass education, 1870–1980. *Sociology of Education*, *65*, 128–149.

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*, 806–829.

Mitch, D. (1992). The rise of popular literacy in Europe. In B. Fuller, & R. Rubinson (Eds.), *The political construction of education: The state, school expansion, and economic change* (pp. 31–46). CT: Praeger.

Modis, T. (2005). Comments on the Huebner article. *Technological Forecasting & Social Change*, *72*, 987–988.

Murray, C. (2003). *Human accomplishment: The pursuit of excellence in the arts and sciences, 800 BC to 1950.* New York, NY: Harper Collins.

Myrskylä, M., Kohler, H. -P., & Billari, F. C. (2009). Advances in development reverse fertility declines. *Nature*, *460*, 741–743.

Neisser, U. (1997). Rising scores on intelligence tests. *American Scientist*, *85*, 440–447.

Neisser, U., Boodoo, G., Bouchard, T. J., Jr., Boykin, A. W., Brody, N., Ceci, S. J., et al. (1996). Intelligence: Knowns and unknowns. *The American Psychologist*, *51*, 77–101.

Nyborg, H. (in press). The decay of Western civilization: double relaxation of Darwinian selection. *Personality & Individual Differences.* doi:10.1016/j.paid.2011.02.031

Osborn, F. (1940). *Preface to eugenics.* New York: Harper Row.

Osborn, F., & Bajema, C. (1972). The eugenic hypothesis. *Social Biology*, *19*, 337–345.

Pettay, J. E., Helle, S., Jokela, J., & Lummaa, V. (2007). Natural selection on female life-history traits in relation to socio-economic class in pre-industrial human populations. *PLoS One*, *2*(7), e606.

Please cite this article as: Woodley, M.A., The social and scientific temporal correlates of genotypic intelligence and the Flynn effect, *Intelligence* (2012), doi:10.1016/j.intell.2011.12.002

Raven, J. (2000). The Raven's progressive matrices: Change and stability over culture and time. *Cognitive Psychology*, *41*, 1–48.
Razi, Z. (1980). *Life, marriage and death in a medieval parish: Economy, society and demography in Halesowen, 1270–1400.* Cambridge: Cambridge University Press.
Retherford, R. D., & Sewell, W. H. (1988). Intelligence and family size reconsidered. *Social Biology*, *35*, 1–40.
Ree, M. J., & Earles, J. A. (1991). *Aptitude of future manpower: Consequences of demographic change.* Texas: Brooks Air Force Base, Manpower and Personnel Division, Air Force Systems Command.
Rindermann, H. (2009). Intelligenz als bürgerliches Phänomen. [Intelligence as bourgeois phenomenon]. *Merkur*, *63(8/723)*, 666–676.
Rindermann, H., Sailer, M., & Thompson, J. (2009). The impact of smart fractions, cognitive ability of politicians and average competence of peoples on social development. *Talent, Development & Excellence*, *1*, 3–25.
Rindermann, H., & Thompson, J. (2011). Cognitive capitalism: The effect of cognitive ability on wealth, as mediated through scientific achievement and economic freedom. *Psychological Science*, *22*, 754–763.
Rodgers, J. L. (1998). A critique of the Flynn effect: Massive IQ gains, methodological artifacts or both? *Intelligence*, *26*, 337–356.
Rodgers, J. L., St John, C. A., & Coleman, R. (2005). Did fertility go up after the Oklahoma City bombing? An analysis of births in metropolitan counties in Oklahoma, 1990–1999. *Demography*, *42*, 675–692.
Rushton, J. P., & Jensen, A. R. (2010). The rise and fall of the Flynn effect as a reason to expect a narrowing of the Black–White IQ gap. *Intelligence*, *38*, 213–219.
Sala-i-Martin, X., & Pinkovskiy, M. (2010). *African poverty is falling… much faster than you think!* National Bureau of Economic Research Working Paper No. 15775.
Schofer, E., & Meyer, J. W. (2005). The worldwide expansion of higher education in the twentieth century. *American Sociological Review*, *70*, 898–920.
Shayer, M. D., & Ginsburg, D. (2009). Thirty years on — A large anti-Flynn effect? (II): 13- and 14-year olds. Piagetian tests of formal operations norms 1976–2006/7. *British Journal of Educational Psychology*, *79*, 409–418.
Skirbekk, V. (2008). Fertility trends by social status. *Demographic Research*, *18*, doi:10.4054/DemRes.2008.18.5
Skjærvø, G. R., Bongard, T., Viken, Å., Stokke, B. G., & Røskaft, E. (2011). Wealth, status, and fitness: A historical study of Norwegians in variable environments. *Evolution and Human Behavior*, *32*, 305–314.
Smart, J. (2005). Measuring innovation in an accelerating world: Review of "A possible declining trend for worldwide innovation", Jonathan Huebner. *Technological Forecasting and Social Change*, *72*, 988–995.
Sorokin, P. A. (1942). *The crisis of our age: The social and cultural outlook.* Boston: E. P. Dutton.
Spengler, O. (1918, 1923/1991). *The decline of the west, abridged version.* New York: Oxford University Press.
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.
Sutherland, H. E. B. (1929). The relationship between IQ and size of a family. *Journal of Educational Psychology*, *20*, 81–90.
te Nijenhuis, J., Murphy, R., & van Eeden, R. (2011). The Flynn effect in South Africa. *Intelligence*, *36*, 456–467.
Teasdale, T. W., & Owen, D. R. (1989). Continuing secular increases in intelligence and a stable prevalence of high intelligence levels. *Intelligence*, *13*, 255–262.
Teasdale, T. W., & Owen, D. R. (2008). Secular declines in cognitive test scores: A reversal of the Flynn effect. *Intelligence*, *36*, 121–126.
Tuddenham, R. D. (1948). Soldier intelligence in World Wars I and II. *The American Psychologist*, *3*, 54–56.
U.S. Census Bureau. (2004a). Historical estimates of world population. http://www.census.gov
U.S. Census Bureau. (2004b). Total midyear population for the world: 1950–2050. http://www.census.gov
Udry, J. R. (1978). Differential fertility for intelligence: The role of birth planning. *Social Biology*, *25*, 10–14.
United Nations (2006). *Human development report 2006.* New York: United Nations.
United Nations Office on Drugs and Crime (2010). UNODC homicide statistics. http://www.unodc.org/unodc/en/data-and-analysis/homicide.html
van Court, M., & Bean, F. D. (1985). Intelligence and fertility in the United States: 1912–1982. *Intelligence*, *9*, 23–32.
Vinge, V. (1993). The coming technological singularity. *Whole Earth Review*, *81*, 88–95.
Vining, D. R. (1982). On the possibility of the re-emergence of a dysgenic trend with respect to intelligence in American fertility differentials. *Intelligence*, *6*, 241–264.
Vining, D. (1995). On the possibility of the reemergence of a dysgenic trend with respect to intelligence in American fertility differentials: an update. *Personality & Individual Differences*, *19*, 259–263.
Weiss, V. (1990). Social and demographic origins of the European proletariat. *Mankind Quarterly*, *31*, 127–152.
Weiss, V. (2008). The population cycle drives human history from a eugenic phase into a dysgenic phase and eventual collapse. *Journal of Social, Political, & Economic Studies*, *32*, 327–358.
Wicherts, J. M., Dolan, C. V., Carlson, J. S., & van der Maas, H. L. J. (2010). Raven's test performance of sub-Saharan Africans: Mean level, psychometric properties, and the Flynn effect. *Learning and Individual Differences*, *20*, 135–151.
Wicherts, J. M., Dolan, C. V., Hessen, D. J., Oosterveld, P., van Baal, G. C. M., Boomsma, D. I., et al. (2004). Are intelligence tests measurement invariant over time? Investigating the nature of the Flynn effect. *Intelligence*, *32*, 509–537.
Woodley, M. A. (2011a). Heterosis doesn't cause the Flynn effect: A critical examination of Mingroni (2007). *Psychological Review*, *118*, 689–693.
Woodley, M. A. (2011b). The cognitive differentiation–integration effort hypothesis: A synthesis between the fitness indicator and life history models of human intelligence. *Review of General Psychology*, *15*, 228–245.
Woodley, M. A. (in press). A life history model of the Lynn–Flynn effect. *Personality & Individual Differences*, doi:10.1016/j.paid.2011.03.028.
Wuchty, S., Jones, B. F., & Uzzi, B. (2007). The increasing dominance of teams in the production of knowledge. *Science*, *316*, 1036–1039.

Please cite this article as: Woodley, M.A., The social and scientific temporal correlates of genotypic intelligence and the Flynn effect, *Intelligence* (2012), doi:10.1016/j.intell.2011.12.002