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Expanding Variance and the Case of Historical Changes in IQ Means: A Critique of Dickens and Flynn (2001)

David C. Rowe
University of Arizona

Joseph L. Rodgers
University of Oklahoma

The Flynn effect is the rise in mean IQ scores during the 20th century, amounting to about 0.33 IQ points per year. Many theoretical explanations have been proposed, though none are universally accepted. W. Dickens and J. R. Flynn's (2001) new approach explains the large IQ changes by means of recursive models of IQ growth. A salient feature of their models is that IQ phenotypes and their supportive environments are correlated; in addition, environmental effects can rebound on phenotypic IQ to increase or lower IQ. In this critique, the authors examine an empirical challenge to their models, which typically imply large changes in IQ variance. However, the historical rise in IQ mean level has not been accompanied by substantial variance changes, a finding inconsistent with the properties of the proposed model.

Flynn (1984, 1987) summarized data from economically developed countries showing massive gains in intelligence test (IQ) scores. In the United States from 1932 to 1978, Flynn calculated a remarkable gain of 0.33 IQ points per year. IQ gains were largest on tests that measured abstract reasoning abilities, such as Raven's Progressive Matrices. Other studies have replicated the Flynn effect (Lynn, 1990; Teasdale & Owen, 2000). In his two original articles, Flynn was cautious about whether the gain was in actual intelligence or in some artifact of measurement. He doubted that gains so massive could be in cognitive abilities, and he questioned whether society's record of intellectual accomplishment had increased at the same rate as that of IQ. Others also doubted that the IQ change was in intellectual ability per se (Brand, 1996; Rushton, 2000).

Alternatively, many scholars have sought substantive explanations, assuming that the Flynn effect is real and related to intellectual ability. Among various theories are those related to nutrition (Lynn, 1990) and collective memory (Mahlberg, 1997), along with educational reform and television viewing. Jensen (1996) proposed a multiplicity hypothesis, suggesting that the Flynn effect is caused by the combination of many different individually small processes.

This massive IQ gain presents a paradox. The genome cannot change that fast, so the causes must come from the environment. However, it also seems unlikely that the environment has changed enough to cause the observed IQ gains, as Dickens and Flynn (2001) discussed. Behavioral genetic studies estimate the additive genetic portion of adult IQ variance to be about 60% (Plomin & Petrill, 1997). However, even given some measurement error (say 5%), the environmental effect would be no more than 35%, too low to explain realistically the size of the historical IQ change. To achieve a 1σ IQ gain in 45–50 years, an environmental improvement on the order of 1.69σ is needed (assuming a path coefficient of $0.35^{1/2} = .63$), placing the top 10% of the 1932 environment into the bottom 34% in 1972. Only environmental influences not existing in the 1930s would seem able to explain such a large IQ gain. Such influences can be identified (e.g., penicillin, television, increasing Cesarean births), but their positive relationship to intelligence has not been established (e.g., television viewing is not widely recognized as a pathway to increased intelligence).

Dickens and Flynn (2001) created a new approach to modeling intelligence that accounts for both rising IQ and the paradox that substantial environmental change appears both prerequisite and implausible to explain the rise. Their models include multiplier effects of an environmental mean change on mean IQ. For instance, a mere 0.5σ change in the environment can magnify into a more than 2σ change in IQ. The mechanism that produces this multiplier effect is a rebound process by which the environment is recursively correlated with genotype.

We admire their models, which explain both historical rise in IQ as well as other features of IQ (e.g., the increase of heritability with age, the relative importance of the nonshared environment, diminishing importance of the shared environment with age, adoption patterns, and educational correlates). Especially, we applaud the use of nonlinear and/or dynamic recursive models of human behavior. In particular, this approach provides a closer match to the reality that is being modeled and is therefore both predictive and explanatory of the underlying processes (as opposed to the solely predictive goals of traditional linear models; see Rodgers, Rowe, & Buster, 1998). However, we also have reservations about certain features of the Dickens and Flynn model, particularly in regard to the way it handles IQ variance.

We appreciate Dickens and Flynn's models for the following reasons:

1. The underlying process, in which individual differences in intelligence are evocative of environmental differences, is plausible and supported by empirical evidence.

David C. Rowe, Division of Family Studies, University of Arizona; Joseph L. Rodgers, Department of Psychology, University of Oklahoma.

Correspondence concerning this article should be addressed to Joseph L. Rodgers, Department of Psychology, 455 West Lindsey Street, Dale Hall Tower, Room 705, University of Oklahoma, Norman, Oklahoma 73019. E-mail: jrodgers@ou.edu

2. Their Model 2 is a nicely operationalized version of this process.

3. Interpretable parameter values cause their models to shed light on several interesting (and challenging) IQ patterns involving both environmental and genetic etiology.

At the same time, we have three fundamental criticisms of their models:

1. They imply increasing IQ variance, which conflicts with empirical evidence.

2. Because there is no explicit link between the models and empirical data, there may well be other weaknesses in the models, and the models may be difficult to falsify.

3. The issue of parsimony is relevant.

This article is primarily devoted to the first criticism above, which produces an empirical challenge to their model. We return to the second and third criticisms in our discussion section.

The Flynn Effect and IQ Variance

This is not the first time we have criticized Flynn for neglecting the variance. Rodgers (1999, p. 346) suggested that the Flynn effect might not be a mean effect at all but rather caused by changing IQ variance and selected samples (a suggestion that was evaluated, then rejected). In this section, we evaluate what Dickens and Flynn's Models 1–3 say about IQ variance.

Critique of Model 1

In Figure 1 we present the classical *AE* model of behavioral genetics. The observed variable, *P*, is a person's phenotype (e.g., an IQ score). The latent variable *A* represents the effects of additive genetic influence. The second latent variable is *E*, representing nonshared environmental influences, which operate to make siblings dissimilar. These are, by definition, uncorrelated with the genetic variation of *A*. In this model, *E* also includes measurement error. If measurement error were known, a third latent variable with a fixed path to the phenotype, *P*, could be added to represent it. The path coefficients on the latent variables are *h* and e_{NSE}, which determine the effect size of genetic and environmental influences, respectively.

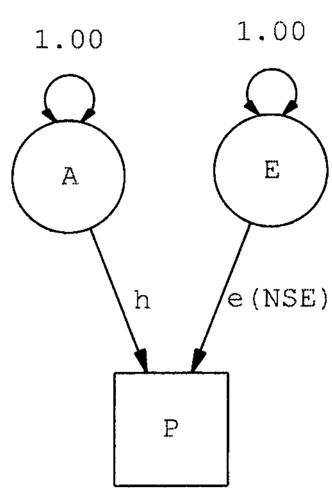

Figure 1. Genetic and environmental influences in an *AE* model. A = additive genetic influence; E = nonshared environmental influences; h = size of genetic influence; e(NSE) = size of environmental influence; P = phenotype.

Assuming uncorrelated genetic and environmental influences is tenable in many cases. For example, carrying a mutated copy of the BRAC1 gene increases breast cancer risk (Ridley, 1999, pp. 190–191). Many environmental influences (e.g., toxins, ionizing radiation) may affect cancer risk but would be unrelated to the possession of this risk-increasing gene. The identity of specific genes involved in IQ phenotypic variation is unknown. However, the principle is the same, in that environmental effects uncorrelated with possession of particular genes may contribute to IQ variance. Such environmental influences might include prenatal traumas, unpredictable effects in early embryonic and fetal development, and accidental life events (e.g., an inspiring teacher).

As Dickens, Flynn, and others have argued genetic effects are correlated with environmental effects as well. Heavy readers gain larger vocabularies than light readers, but they also may possess gene variants favorable to higher IQ. Historically, this genotype–environment correlation has probably increased. For example, in 1900 many people worked on farms; today most individuals work in more or less intellectually demanding jobs. The extent to which modern occupations are more evocative of genetic tendencies would raise the genotype–environment correlation for IQ (e.g., Herrnstein & Murray, 1994; Rowe, Jacobson, & Van den Oord, 1999).

Dickens and Flynn (2001) developed three models of increasing complexity that assumed different degrees of Genotype × Environment correlation to provide a multiplier effect of mean environmental changes on mean IQ. The first model they regard as inadequate to account for the Flynn effect and the associated environmental paradox. Nonetheless, its simplicity makes it a good starting point to consider the implication of their models for IQ variance.

In Dickens and Flynn's (2001) Figure 2, genotype (*G*) is assumed to be a standardized latent variable. The environment (*e*) has a unit variance, but its mean may increase over time from zero (i.e., if it goes to 0.5, then the environment has improved by 0.5σ). *E* allows for *G*–*e* correlation, estimated in *r*. In traditional *AE* models, $r = 0$. The symbol v represents the effect of environment on IQ, defined as *M*. There is also a direct genetic effect, *a*, from genotype to phenotype.

On the basis of their path model, the expected value of the IQ mean (M_j) is

$$E(M_j) = E[aG_j + v(rG_j + e_j)] = E[(a + vr)G_j + ve_j], \quad (1)$$

where *E* is the expectation operator. Because *G* in Equation 1 is assumed to have a mean of zero,

$$E(M) = vE[e_j]. \quad (2)$$

This simplification shows that in Model 1 the environmental effect on the mean depends on the path coefficient v and the mean of the environment. For instance, if $v = .90$ and the environment improved by 0.45 standard deviation, then the expected mean gain in the phenotype is 0.41.

Dickens and Flynn (2001) argued that v can be a high value, but less than 1.0, when the genotype–environment correlation is strong. In contrast, the maximum e_{NSE} in the *AE* model is limited to

$$(1 - h^2)^{1/2} = (e_{NSE}), \quad (3)$$

where the path coefficients are defined as in Figure 1. Thus, in the *AE* model, the heritability (h^2) restricts the size of the environmental path, leading to the paradox of both prerequisite and implausible high-environmental influence. Compared with the *AE* model, Dickens and Flynn's v can be larger than e_{NSE} (but still not > 1.0), at least reducing the magnitude of the paradox. Their article provides a mathematical derivation of this phenomenon, which depends on the value of r.

However, they neglected to consider another consequence of increasing r: It necessarily raises the variance of the IQ phenotype. Applying variance–covariance algebra (e.g., Loehlin, 1992) to the standardized variables in their path model, the IQ variance is

$$V_M = a^2V_G + v^2V_E + 2_{avr}. \tag{4}$$

The last term is brought about by the *G–e* covariance, that is, of genotype and environment. The effect of a positive *G–e* covariance is to increase IQ variance, and this positive covariance will come about as long as a, v, and r are all positive, as they will be within any reasonable model.

To illustrate, we computed IQ variance for several different parameter combinations (see Table 1). We fixed $a = 7$ so that the direct genotypic effect was 49% of total variance. IQ variance increases as environmental effects increase in either of two ways: by increasing *G–e* correlation (r) or by increasing environmental effect on IQ (v). When $v = .3$, as the *G–e* correlation increases, IQ variances increase from 0.58 to 0.92, a 59% increase. For $v = .7$, the increase was from 0.98 to 1.76, an 80% increase. An examination of rows shows that strengthening the environmental effect also causes a larger IQ variance. When $r = .8$ and $v = .5$, adding .4 to v yields an 86% increase.

Thus, unless we assume that the *G–e* correlation has been static historically, this model implies positive, potentially large change in IQ variance. The same applies to any change in the environmental effects (v). If the data fail to demonstrate systematic historical changes in IQ variance (as we demonstrate later), the only consistent explanation is that the *G–e* correlation was already high in the early part of the century, permitting the environmental mean to rise and increase IQ means without increasing IQ variance. However, here we return full circle to the original paradox: What favorable environmental influence has increased in mean and is highly correlated with IQ yet has not historically become any more correlated with IQ phenotype?

Dickens and Flynn suggested that even under a scenario of a large v (about 1.0), it would take an unrealistic environmental improvement to produce sufficient gain in IQ under Model 1. As a result, they developed Model 2, which has the same problem with increasing IQ variance.

Table 1
Variance (V) Estimates From a = .7 in Dickens and Flynn's (2001) Model 1

r	$v = .3$	$v = .5$	$v = .7$
0	0.58	0.74	0.98
.1	0.62	0.81	1.08
.2	0.66	0.88	1.18
.3	0.71	0.95	1.27
.4	0.75	1.02	1.37
.5	0.79	1.09	1.47
.6	0.83	1.16	1.57
.7	0.87	1.23	1.67
.8	0.92	1.30	1.76

Critique of Model 2

In Model 2, IQ (M) affects the environment, which then has a rebound effect on IQ. The model is mathematically operationalized as a set of difference equations, with the environment affecting IQ from the previous time period. As shown in Dickens and Flynn's (2001) Figure 2 (p. 354), the effect of IQ on environment is b, the effect of environment on IQ is v, and a direct genotypic effect is a. At the start of the process, $t = 0$, only one influence produces variation in the IQ phenotype M_0, namely the direct genetic effect a. At all later time points, however, environmental effects are added as a component of IQ variance. At each time point, the path coefficient v contributes to IQ variation. Using path algebra, the IQ variance at $t = 0$ for Model 2 is $V_{M0} = a^2$; at $t = 1$, $V_{M1} = a^2 + v^2 + 2(ab)$; at $t = 2$, $V_{M2} = a^2 + v^2 + 2(ab)(1 + bv)$; and at $t = 3$, $V_{M3} = a^2 + v^2 + 2(ab)(1 + bv + b^2v^2)$. The IQ variance at a general time $t = k$ can be expressed as

$$V_{Mk} = a^2 + v^2 + 2(ab) \sum_{i=0}^{k} (b^i v^i). \tag{5}$$

The dynamics of this equation depend on the parameters, a, v, and b and the multiplier effect indicating how much the IQ mean would grow (in σ units) when the exogenous environmental mean of u changes by 1σ. The equation for the multiplier effect is

$$MP = v/(1 - bv). \tag{6}$$

This multiplier shows that an increase of the environmental mean can magnify into a greater increase in mean IQ. Dickens and Flynn found particularly useful regions of the parameter space in which $MP > 1$, which can successfully reproduce the massive IQ gains of the Flynn effect.

There is also concern about the scaling of the variables in their Figure 2. Dickens and Flynn (2001) said that they are measured "in terms of standard deviations from their respective means" (p. 354). Dickens indicated that they should have added "at equilibrium" (W. T. Dickens, personal communication, October 2001). Further, the question of how the standardization process scales these values over time is important as well: Are *E*s and *M*s standardized within time periods or overall? We note that although these issues affect the path algebra of variances computation, different answers do not change the final result: Model 2 implies typically increasing IQ variance.

Suppose that the process has reached equilibrium. In this situation, the variance could be unchanging and the multiplier effect could still be large. However, this conclusion assumes that the values of v and b remain constant historically, because any change in them would produce a new equilibrium for Dickens and Flynn's Equation 7. We believe that an assumption of historically stable v and b is implausible. Any new source of environmental influence should change v. Alternatively, changes in social structure (e.g., a college or occupational selection process more strongly based on IQ; Herrnstein & Murray, 1994) should alter b by increasing the IQ–environment correlation. Thus, variance changes as well as mean changes would be expected.

Dickens and Flynn presented alternative interpretations of the environmental effect in their Model 2. One was that the IQ multiplier, created by an individual's phenotype originated in the environment (*E*). Yet the environmental mean was set by an exogenous environment that an individual's IQ cannot affect. Perhaps the path *b* corresponds to a high-IQ person reading more books (*E*). The exogenous environment includes societal availability of books. Therefore, if society moved from having no books to having many libraries, the exogenous mean (*u*) would increase. However, this line of thinking also implies an historical change in *b* itself. If books were unavailable, then the link between phenotype, *M*, and reading material, *E*, would be weak, say $b < 0.3$. As books were better distributed, a difference in book reading between bright and dull individuals may increase as they act on their reading preferences. Suppose that under this condition, $b > 0.7$. Such an increase in *b*, however, could easily move the model into a region of the parameter space in which IQ variance would grow rapidly.

In reviewing this comment, Dickens (W. T. Dickens, personal communication, January 2002) has noted that we assume that the environmental variance is fixed at unity in our development, even as the other parameters are changing. It is interesting that, even with environmental variance fixed, the Dickens and Flynn (2001) model nevertheless implies increasing variance in overall IQ. Although the fixed environmental variance assumption may be problematic, we note (and Dickens agrees) that this is a conservative assumption in relation to our concern over the model's implication of increasing variance in overall IQ: If the environmental variance is allowed to vary within the model, then the overall IQ variance will increase even more than we have suggested.

Critique of Model 3

Dickens and Flynn's (2001) Model 3 is an extension of Model 2 that adds a group-average IQ effect. Specifically, this model possesses an additional assumption that an individual's IQ is sensitive to the average IQ of persons in his or her environment. Further, the dynamics described above that create variance concerns over Model 2 are still represented within Model 3.

We do believe that evidence exists for the influence of environment on IQ, as shown by significant c^2 estimates for children's IQ. Nonetheless, sharing a family environment hardly forces IQ similarity on siblings. For example, full siblings share many aspects of the environment but differ in IQ by, on average, about 10 to 12 IQ points, with many sibling pairs having an even more extreme IQ difference (Rodgers & Rowe, 1987, p. 203). Similarly, school systems have used tracking as a means of equating abilities of children in a classroom. In some school districts, tracking was abandoned as educational philosophies changed. In the absence of tracking, low-IQ students were placed among classmates of higher average IQ. However, we know of no reports of dramatic IQ gains among the lower IQ students because ability tracks were abandoned in schools.

Historical Patterns of IQ Variance: The Empirical Evidence

Rodgers (1999) noted that a changing mean in a distribution leaves in doubt who in the population experienced change. IQ change could occur in all of the distribution or in just some part of it, with different causal implications. If changes were concentrated among low-IQ individuals, then ameliorative changes in harmful environments should be considered as probable causes. If the rising mean were driven by the smart getting smarter, then the change might reflect the introduction of some qualitatively novel form of environmental stimulation. If the overall distribution increased in pace, the cause would lie in processes that affected everyone equally.

Rodgers (1999) noted a phenomenon relevant to Dickens and Flynn's (2001) models. Changes in variance can mimic changes in means, in two different ways. First, decreasing variance in the lower tail or increasing variance in the upper tail will create an apparent upward mean change. Second, if a sample is selected, then variance changes will appear to be mean changes (see Rodgers, 1999, Figure 2, p. 346, for a graphical presentation of this argument). Using Flynn's (1984) data, Rodgers (1999) found no systematic pattern of association between sample means and variances, suggesting that "the cause of the Flynn effect is not an overall change in the variance" (Rodgers, 1999, p. 349).

These data can be reconfigured to calculate the variance by year of the test from Rodgers' (1999) Table 1 on the basis of Flynn's (1984) standard deviations. In Table 2 in this article, historical changes in IQ variance are presented by the median standard deviation for the median year. Standard deviations ranged from 9 to 14.9. In all years except 1971.5, the samples had restricted variances (compared with IQ-test norms with $\sigma = 15$ or 16), suggesting unrepresentative samples. No discernable (or statistically significant) historical trend exists in the IQ variances in our Table 2, however. Other empirical studies suggest that IQ gains are concentrated in the lower half of the distribution (Herrnstein & Murray, 1994, p. 308; Teasdale & Owen, 1989, 2000), which would reduce total variances if the upper part of the distribution remained approximately constant. Thus, empirical data suggest that IQ variances have remained unchanged or may even have shrunk during recent history.

Discussion

We find a model including a phenotype–environment correlation, like that in Dickens and Flynn's (2001) Model 2, to be reasonable and plausible. However, features of the model raise three important questions. First, the model implies increasing IQ variance under typical parameter specifications. Yet empirical evidence suggests that IQ variance has not increased, and may even have declined.

Table 2
Historical Changes in Standard Deviations on IQ Tests

Year	*SD*	$SD - M_{SD}$
1932	9.7	−1.51
1936.5	10.1	−1.11
1947.5	13.2	1.99
1953.5	9.0	−2.21
1964.5	10.8	−0.41
1971.5	14.9	3.69
1972	10.8	−0.41

Note. Calculated from Table 1 in Rodgers (1999). $SD - M_{SD}$ is the difference of the standard deviation from the mean of the standard deviations, where $M_{SD} = 11.21$.

Second, the model has not been fit to empirical data. Rather, its performance was evaluated by specifying different (nonoptimized) parameter values and observing the results. Then, they were compared with patterns in the literature. Dickens and Flynn discussed the difficulty of finding appropriate data. Although we are not as pessimistic about data availability as they are, we recognize the problem. However, we also have concern over model fixes and adjustments when those were created to match external empirical patterns, without mechanisms to evaluate their legitimacy. Further, in a related concern, we wonder whether the model can be falsified. What types of patterns would do so? Can we distinguish between incorrectness at a fundamental level, as opposed to problems in some particulars (to which mathematical fixes can be applied)?

Third, we note that more conventional processes—based on more parsimonious models—can account for some IQ gain. Rowe, Jacobson, and Van den Oord (1999) found that genetic and environmental components of IQ variance were moderated by socioeconomic status (SES). In the bottom 20% of the SES distribution, $c^2 = .40$, whereas it was approximately zero in the remainder of the distribution (a result replicated by Thompson, Tiu, & Detterman, 1999). To further elaborate, shared environmental effects were strongest where there was greatest potential of improvement in environmental circumstances. Some part of the Flynn effect may have derived from improved environmental conditions for poor families. As Dickens and Flynn suggested, this effect size may be no more than one third of a standard deviation, too little to be viewed as a complete explanation of the historical change. However, the simplicity of this explanation (and others reviewed earlier) provides a stark contrast to the complexity of Dickens and Flynn's Model 3.

There is no simple research design to account for historical IQ change (see Rodgers, 1999, for discussion). We mention several design considerations. New data would help, especially longitudinal- and individual-level data that would also measure which part of the IQ distribution has changed. One possible design is testing twin pairs of different ages on both old and new IQ tests and assessing their scores against current versus outdated norms. According to the historical change hypothesis, (a) younger twin pairs should outperform older ones, and all should look more intelligent on a test based on outdated norms; and (b) the historical shared environmental effect should appear when twins are analyzed together but disappear when old or young twins, born to different birth cohorts, are analyzed. Further, using twins would permit estimates of shared environmental variance and heritability of IQ, and moderation of variance components by birth cohort.

Designs and models used to evaluate the nature of the Flynn effect may soon have broader importance, as other domains beyond intelligence have been shown to have similar secular trends. For example, Twenge (2000) reported a meta-analysis showing increasing levels of anxiety and neuroticism, and Twenge (2001) showed secular trends in extraversion. Eventually, multivariate models may be necessary to account for covariance among these variables as well as secular changes in their means.

It seems unlikely that designs such as those we have described above would show IQ variance difference between birth cohorts, which speaks to our concern with the Dickens and Flynn models. In models that predict large variance changes, stable variances are a theoretical liability. Until new data are collected or older data sets used in creative ways, the Flynn effect may well retain its status as an interesting but still unexplained curiosity in the history of IQ testing.

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