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The nature of nurture: the role of gene-environment interplay in the development of intelligence

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Publication date
2012

[Link to publication](#)

Citation for published version (APA):

Kan, K.-J. (2012). *The nature of nurture: the role of gene-environment interplay in the development of intelligence*. [Thesis, fully internal, Universiteit van Amsterdam].

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APPENDIX B

SETUP OF THE SIMULATIONS IN CHAPTER 7

The mutualism package, codes of basic simulations with the mutualism model, and the codes pertaining to the simulations in Chapter 7 can be found at http://hvandermaas.socsci.uva.nl/Homepage_Han_van_der_Maas/Home.html. The mutualism model used in these simulations is formulated mathematically as follows:

$$\frac{dx_i}{dt} = a_i x_i (1 - x_i / K_i) + a_i \sum_{\substack{j=1, \\ j \neq i}}^W M_{ij} x_j x_i / K_i \quad \text{for } i, j = 1 \dots W.$$

The covariance matrix of the observed x variables in equilibrium is:

$$\Sigma = [\mathbf{I} - \mathbf{M}]^{-1} \Psi [\mathbf{I} - \mathbf{M}]^{-T}$$

where Ψ is a diagonal matrix containing the variances of the K 's, and \mathbf{I} is the identity matrix. Superscript -1 denotes matrix inversion, and superscript -T denotes inversion and transposition.

In the simulations in Chapter 7, we generated data for $W = 17$ variables (8 fluid abilities, 8 crystallized abilities, and 1 environmental variable). The K 's are normally distributed with means of 3 and SD's 0.5. Parameters a are normally distributed with means of 6 (unless stated otherwise) and SD's 0.5. \mathbf{M} is taken as in Figure B.1. Values *ec* and *ce* are always set equal. Values *cc* are always set 0.

Highest g loadings and heritabilities for crystallized abilities could be obtained in multiple ways (see and below, and Table B.1). Two categories of simulations can be made. In the first category, simulations were based on the covariance matrix, i.e., when systems are in equilibrium (see the mutualism R help file, topic Jensen effect). In the second category simulations are based on the mutualism model (see van der Maas et al, 2006, and the mutualism R help file).

Fluid abilities (x_f)	Crystallized abilities (x_c)	Cognitive environment (x_e)
00 ff ff ff ff ff ff ff	cf cf cf cf cf cf cf cf	ef
ff 00 ff ff ff ff ff ff	cf cf cf cf cf cf cf cf	ef
ff ff 00 ff ff ff ff ff	cf cf cf cf cf cf cf cf	ef
ff ff ff 00 ff ff ff ff	cf cf cf cf cf cf cf cf	ef
ff ff ff ff 00 ff ff ff	cf cf cf cf cf cf cf cf	ef
ff ff ff ff ff 00 ff	cf cf cf cf cf cf cf cf	ef
ff ff ff ff ff ff 00	cf cf cf cf cf cf cf cf	ef
fc fc fc fc fc fc fc fc	00 cc cc cc cc cc cc cc	ec
fc fc fc fc fc fc fc fc	cc 00 cc cc cc cc cc cc	ec
fc fc fc fc fc fc fc fc	cc cc 00 cc cc cc cc cc	ec
fc fc fc fc fc fc fc fc	cc cc cc 00 cc cc cc cc	ec
fc fc fc fc fc fc fc fc	cc cc cc cc 00 cc cc cc	ec
fc fc fc fc fc fc fc fc	cc cc cc cc cc 00 cc cc	ec
fc fc fc fc fc fc fc fc	cc cc cc cc cc cc 00	ec
fc fc fc fc fc fc fc fc	cc cc cc cc cc cc cc	00

Figure B.1 Generalized design Matrix M used in the simulations in Chapter 7.

Category 1

Variant 1: fc is positive, other values in \mathbf{M} are zero, and intercorrelations between the Kg 's are high. This variant can be regarded as a revision of investment theory. Here, g represents the total genetic value of the genes that influence the limited capacities which constrain the growth of fluid and crystallized abilities.

Variant 2: ff and cf are positive and relatively low, fc is positive and relatively high, fe , ce and ec are large (and equal), while other weights in \mathbf{M} are 0, and the Kg 's are intercorrelated. Only weak intercorrelations are required. This is a scenario in which mutualism, a multiplier effect, and genetic sampling are present. The environment selects on general intelligence (both fluid and crystallized abilities), but gives practice primarily in crystallized abilities.

Category 2

Variant 3: All ff and cf are positive and relatively low, fc are positive and relatively high, fe , ce and ec are large (and equal), while all other weights in \mathbf{M} are 0, and the subjects sample is assumed to be heterogeneous. This is a scenario in which mutualism, and a multiplier effect are present. The cognitive environment selects on general intelligence, but gives practice primarily in crystallized abilities.

Variant 4: All ff and cf are positive and relatively low, fc are positive and relatively high, ce and ec are large (and equal), while all other weights in \mathbf{M} are 0 and the subjects sample is assumed to be heterogeneous. This is a scenario in which mutualism and a multiplier effect are present. The cognitive environment primarily selects on, and is conducive to practice in crystallized abilities. Heterogeneity can be introduced by specifying larger a 's for crystallized abilities than fluid abilities, while t is equal over subjects (in our simulations t is set at 1), or by assuming normally distributed a 's with equal means and heritable t (in our simulations t is normally distributed, with mean 1, and SD = .02).

Table B.1 Assumptions under which crystallized abilities have higher heritabilities than fluid abilities. The effect can be obtained in multiple ways.

Variant	Mutualism is present	Systems in equilibrium	Multiplier is present	Environment selects on	Environment gives practice in	Genetic sampling is present
1	Yes	Yes	No	-	-	Yes, high overlap (some general genes)
2	Yes	Yes	Yes	General intelligence	Crystallized intelligence	Yes, low overlap (no general genes)
3	Yes	No	Yes	General intelligence	Crystallized intelligence	No, not necessarily
4	Yes	No	Yes	Crystallized intelligence	Crystallized intelligence	No, not necessarily