School, neighbourhood and family contributions to pupils' progress

Jon Rasbash, George Leckie, Rebecca Pillinger and Jenny Jenkins

1. Partitioning variation in progress

What do we already know?

	①		②	③	④		⑤		⑥	⑦		⑧
Response	Prog	Prog	Prog	Att	Att	Prog	Att	Prog	Att	Att	Prog	Cog
Predictors	Y	Y	Y	N	N	Y	N	Y	N	N	Y	N
LEA			0.2	3								
Neighbhd				2	20	4	14	1	5	4	1	0.20
Secondary	5—20		5	22		fixed	7	1	20	23	4	
Primary		5—20								3	7	
Cohort			3									0.21
Pupil	80—95	80—95	93	73	80	96	79	98	75	70	88	
MZ twins												0.78
DZ twins												0.64
Full sibs												0.51

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	1	2	3	4	5	6	7	8	9	10	11	12
Response	Att	Att	Att	Att	Att	Att	Att	Att	Att	Att	Att	Att
Predictors	N	N	N	N	N	N	N	N	N	N	N	N
LEA Neighbhd												
Secondary Primary												
Cohort												
Non-shared envt	0	43	10	10	6	11	24	29	14	9	23	24
Genetic	38	21	17	53	28	53	60	36	67	67	68	49
Shared envt	62	36	73	37	66	36	16	35	19	24	9	27

1. Cardon et al. (1990); reading recognition
2. Brooks et al. (1990); spelling
3. Thompson et al. (1991); maths
4. Thompson et al. (1993); composite of WRAT-R and MAT
5. Petrill & Thompson (1993); MAT
6. Petrill & Thompson (1994); MAT
7. Van den Oord & Rowe (1997); PIAT
8. Cleveland et al. (2000); composite of PPVT and PIATS
9. Wainwright et al. (2005); QCST, Australian data
10. Friend et al. (2007); spelling production (WRAT)
11. Haworth et al. (2007); maths, UK data
12. Haworth et al. (2008); science, UK data

Previous studies

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- Models usually have pupils within schools (2 levels)

Developmental Psychology

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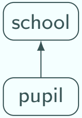

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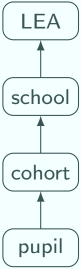

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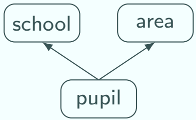

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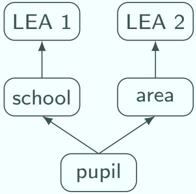

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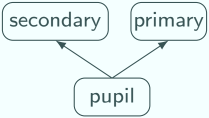

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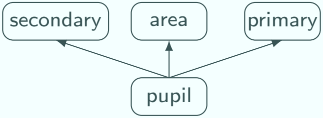

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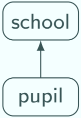

Model

$$y_{ij} = \alpha + \beta x_{ij} + u_j + e_{ij},$$

$$\begin{aligned} u_j &\sim \mathrm{N}\left(0, \sigma_u^2\right), & i &= 1, \ldots, n_j \\ e_{ij} &\sim \mathrm{N}\left(0, \sigma_e^2\right), & j &= 1, \ldots, J \end{aligned}$$

(B)

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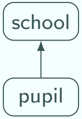

Model

$$\mathbf{GCSE}_{ij} = \alpha + \beta\mathbf{pretest}_{ij} + u_j + e_{ij},$$

$$u_j \sim \mathrm{N}\left(0, \sigma_u^2\right), \qquad i = 1, \ldots, n_j$$
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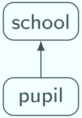

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$$\mathbf{GCSE}_{ij} = \alpha + \beta_1 \mathbf{pretest}_{ij} + \beta_2 x_{ij} + u_j + e_{ij},$$

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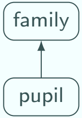

Developmental Psychology

- Models usually have children within families
- Researchers recognise that really these models partition into shared environment and non-shared environment
- What is the shared environment?
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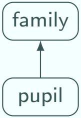

Model

$$y_{ij} = \alpha + u_j + e_{ij} + g_{ij}$$

$$u_j \sim N(0, \sigma_u^2)$$
$$e_{ij} \sim N(0, \sigma_e^2)$$
$$g_{ij} \sim N(0, \sigma_g^2)$$

$$\text{Cov}(g_{i_1 j}, g_{i_2 j}) = r_{(i_1 j, i_2 j)} \sigma_g^2$$

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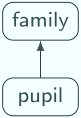

Model

$$y_{ij} = \alpha + d_j u_{1j} + d_j e_{1ij} + (1 - d_j) e_{2ij}$$

$$u_{1j} \sim \mathrm{N}\left(0, \sigma_u^2\right)$$

$$\begin{bmatrix} e_{1ij} \\ e_{2ij} \end{bmatrix} \sim \mathrm{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{e1}^2 & \\ 0 & \sigma_{e2}^2 \end{bmatrix} \right)$$

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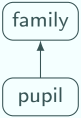

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$$\mathbf{GCSE}_{ij} = \alpha + u_{1j}\mathbf{twin}_j + e_{1ij}\mathbf{twin}_j + e_{2ij}\mathbf{nontwin}_j$$

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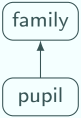

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$$\mathbf{GCSE}_{ij} = \alpha + \beta_1 \mathbf{pretest}_{ij} + \beta_2 \mathbf{twin}$$
$$+ \beta_3 \mathbf{twin}_j \cdot \mathbf{pretest}_{ij}$$
$$+ u_{1j} \mathbf{twin}_j + e_{1ij} \mathbf{twin}_j$$
$$+ e_{2ij} \mathbf{nontwin}_j$$
$$u_{1j} \sim \mathrm{N}\left(0, \sigma_u^2\right),$$
$$\begin{bmatrix} e_{1ij} \\ e_{2ij} \end{bmatrix} \sim \mathrm{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{e1}^2 & \\ 0 & \sigma_{e2}^2 \end{bmatrix} \right) \quad \text{(A)}$$

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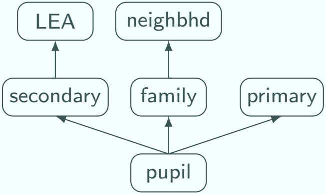

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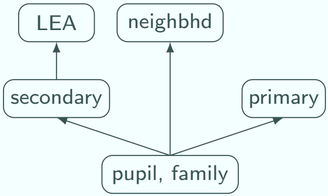

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Model

$$y_i = \alpha + \beta x_i + u^{(6)}_{\text{LEA}(i)} + u^{(5)}_{\text{sec}(i)} + u^{(4)}_{\text{nbhd}(i)} + u^{(3)}_{\text{pri}(i)} + u^{(2)}_{\text{fam}(i)} d_{\text{fam}(i)} + e_{1i} d_{\text{fam}(i)} + e_{2i}\left(1 - d_{\text{fam}(i)}\right)$$

$$u^{(6)}_{\text{LEA}(i)} \sim \text{N}\left(0, \sigma^2_{u(6)}\right)$$

$$\vdots \qquad \vdots$$

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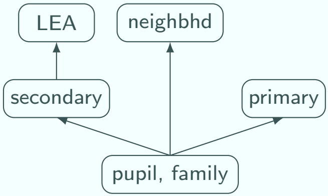
$$\begin{bmatrix} e_{1i} \\ e_{2i} \end{bmatrix} \sim \text{N}\left(0, \begin{bmatrix} \sigma^2_{e1} & \\ 0 & \sigma^2_{e2} \end{bmatrix}\right) \qquad \text{(C)}$$

Classification diagram



Our model

Model

$$\textbf{GCSE}_i = \alpha + \beta_1 \textbf{pretest}_i + \beta_2 \textbf{twin}_i + \beta_3 \textbf{pretest} \cdot \textbf{twin}_i$$
$$+ u^{(6)}_{\text{LEA}(i)} + u^{(5)}_{\text{sec}(i)} + u^{(4)}_{\text{nbhd}(i)} + u^{(3)}_{\text{pri}(i)}$$
$$+ u^{(2)}_{\text{fam}(i)} \textbf{twin}_{\text{fam}(i)} + e_{1i} \textbf{twin}_{\text{fam}(i)} + e_{2i} \textbf{nontwin}_{\text{fam}(i)}$$

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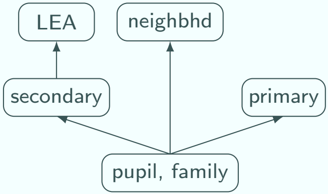

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All pupils in

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Size of dataset

551,220 pupils	30507 LSOAs	3099 secondaries
5116 twin pairs	14765 primaries	149 LEAs

Results

	Model A		Model B		Model C		Model D	
cons	−0.003	(0.001)	−0.003	(0.001)	0.001	(0.008)	−0.039	(0.007)
twin	0.177	(0.008)	0.179	(0.007)	0.162	(0.007)	0.154	(0.007)
pretest	0.730	(0.001)	0.729	(0.001)	0.701	(0.001)	0.641	(0.001)
pretest.twin	−0.040	(0.007)	0.000	(0.007)	−0.027	(0.006)	−0.020	(0.006)
female							0.184	(0.002)
Asian							0.429	(0.005)
Black							0.225	(0.006)
Chinese							0.556	(0.015)
Mixed							0.045	(0.005)
Other							0.403	(0.010)
FSM							−0.248	(0.003)
age							−0.012	(0.000)
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IDACI							−0.103	(0.001)
LEA					0.005	(0.001)	0.005	(0.001)
Secondary			0.065	(0.002)	0.043	(0.001)	0.035	(0.001)
Primary					0.035	(0.001)	0.025	(0.000)
LSOA					0.008	(0.000)	0.002	(0.000)
Family (twin)	0.238	(0.007)			0.168	(0.005)	0.157	(0.005)
Pupil (twin)	0.160	(0.003)			0.157	(0.003)	0.150	(0.003)
Pupil (non-twin)	0.468	(0.001)	0.402	(0.002)	0.383	(0.001)	0.357	(0.001)

Using MCMC; 450,500 iterations and a burn-in of 50,000

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Variance partitioning coefficients

	A	B	C		D	
			Twins	Non-twins	Twins	Non-twins
LEA			1.2%	1.1%	1.3%	1.2%
Secondary		13.9%	10.3%	9.1%	9.4%	8.3%
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LSOA			1.9%	1.7%	0.5%	0.5%
Family	59.8%		40.4%		42.0%	
Pupil	40.2%	86.1%	37.7%	80.8%	40.1%	84.2%

Research questions

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What happens when we try to explain some of the variation using pupil, family and LSOA level covariates?

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- To what extent can we generalise to other family types?
  - e.g. single child families

2. What happens under stress?

Variance functions for stress

Data

- Data is from previous cohort, who took GCSEs in 2006

Model

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- Our main stressor was IDACI, an LSOA level variable

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Stressors

- Our main stressor was IDACI, an LSOA level variable
- It aims to measure income deprivation affecting children

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Variance functions for stress

Data

- Data is from previous cohort, who took GCSEs in 2006
- Postcodes with more than 2 students excluded
- Continuous variables not standardized

Stressors

- Our main stressor was IDACI, an LSOA level variable
- It aims to measure income deprivation affecting children
- Other stressors included:
  - FSM eligibility
  - House moves

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Model

$$
\begin{aligned}
\textbf{GCSE}_{ijk} = \alpha + \beta_1 \textbf{pretest}_{ijk} + \beta_2 \textbf{twin}_{jk} + \beta_5 \textbf{stressor}_{jk} \\
+ v_{0k} + u_{2jk}\textbf{twin}_{jk} + e_{2ijk}\textbf{twin}_{jk} + e_{3ijk}\textbf{nontwin}_{jk} \\
+ u_{4jk}\textbf{twin} \cdot \textbf{stressor}_{jk} + e_{4ijk}\textbf{twin} \cdot \textbf{stressor}_{jk} \\
+ e_{6ijk}\textbf{nontwin} \cdot \textbf{stressor}_{jk}
\end{aligned}
$$

Variance functions for stress

Covariance structure

$$\begin{bmatrix} v_{0k} \end{bmatrix} \sim N\left(0, \begin{bmatrix} \sigma^2_{v0} \end{bmatrix}\right)$$

$$\begin{bmatrix} u_{2jk} \\ u_{4jk} \end{bmatrix} \sim N\left(0, \begin{bmatrix} \sigma^2_{u2} & \\ \sigma_{u24} & \sigma^2_{u4} \end{bmatrix}\right)$$

$$\begin{bmatrix} e_{2ijk} \\ e_{3ijk} \\ e_{4ijk} \\ e_{6ijk} \end{bmatrix} \sim N\left(0, \begin{bmatrix} \sigma^2_{e2} & & & \\ 0 & \sigma^2_{e3} & & \\ \sigma_{e24} & 0 & \sigma^2_{e4} & \\ 0 & \sigma_{e36} & 0 & \sigma^2_{e6} \end{bmatrix}\right)$$

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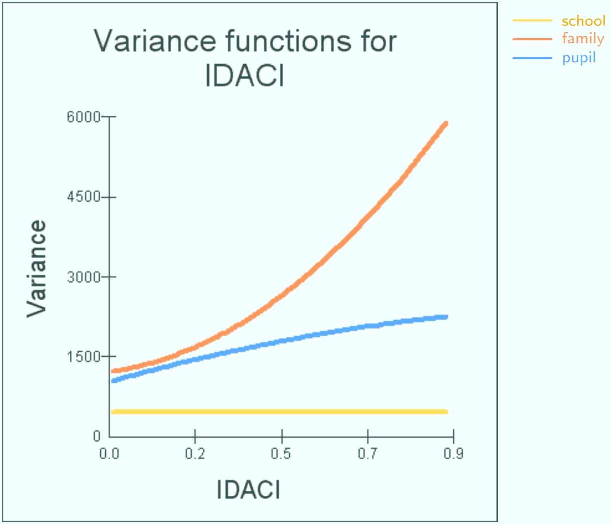
Model

$$\begin{aligned} \mathbf{GCSE}_{ijk} = \alpha &+ \beta_1 \mathbf{pretest}_{ijk} + \beta_2 \mathbf{twin}_{jk} + \beta_5 \mathbf{IDACI}_{jk} \\ &+ v_{0k} + u_{2jk}\mathbf{twin}_{jk} + e_{2ijk}\mathbf{twin}_{jk} + e_{3ijk}\mathbf{nontwin}_{jk} \\ &+ u_{4jk}\mathbf{twin} \cdot \mathbf{IDACI}_{jk} + e_{4ijk}\mathbf{twin} \cdot \mathbf{IDACI}_{jk} \\ &+ e_{6ijk}\mathbf{nontwin} \cdot \mathbf{IDACI}_{jk} \end{aligned}$$

Results



Variance functions for IDACI
6000
4500
3000
1500
0
Variance
0.0
0.2
0.5
0.7
0.9
IDACI
school
family
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Interpreting the results

As IDACI increases,

We have this situation:

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- The mean progress decreases
  - $\beta_5 = -68.1$

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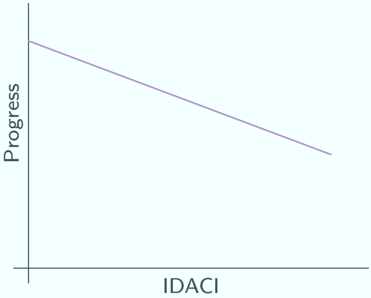

Interpreting the results

As IDACI increases,

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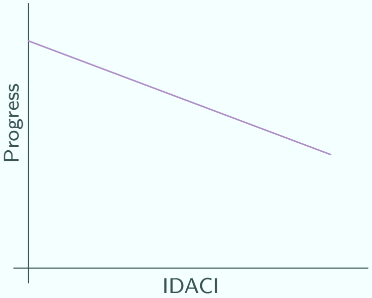

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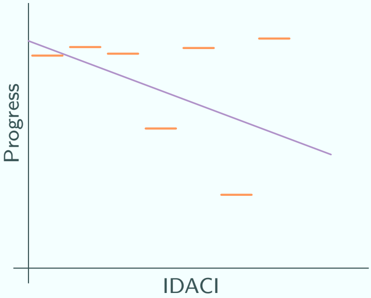

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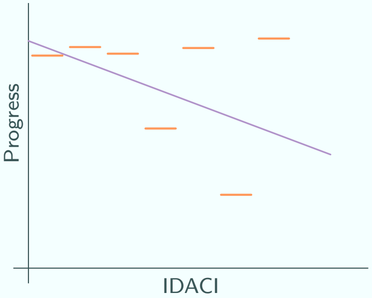

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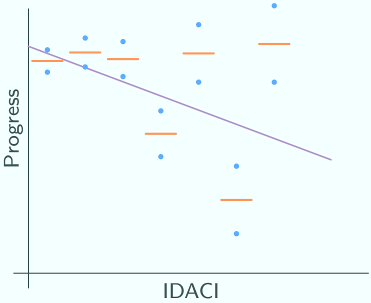

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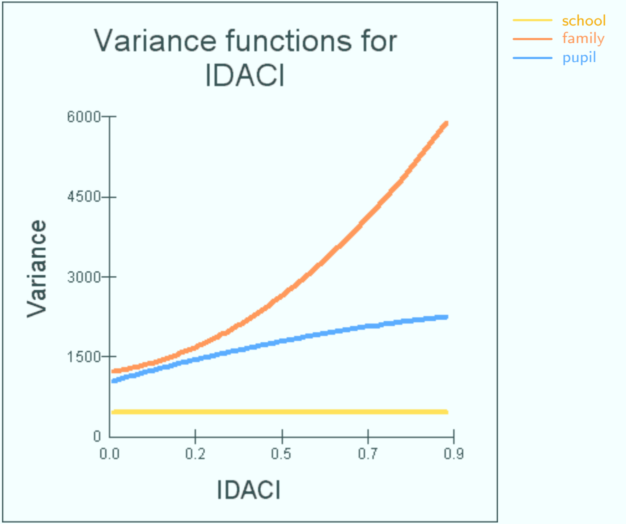

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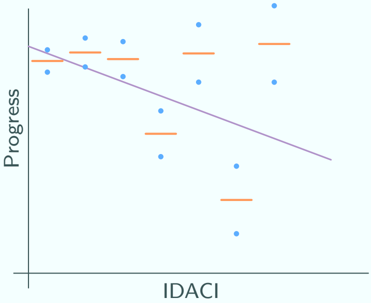

- Between family variation increases more dramatically than within family variation
- So at greater levels of deprivation, family becomes relatively more important in determining progress

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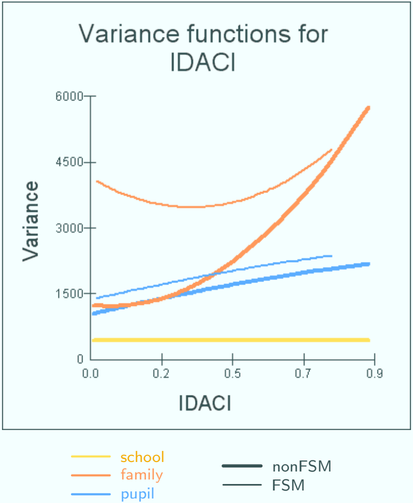

What's going on? Possible explanations

Genetic explanation

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- In the presence of stressors, families with these factors cannot do so → variability since some families have these factors and some don't

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Environmental explanation

- Children in families compete for resources
- In the absence of stressors, there are enough resources for the needs of all children
- In the presence of stressors, there are fewer resources and some children will have their needs met while others will not $\longrightarrow$ variability since those getting more resources can make more progress

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