



Integrative **A**nalysis of **L**ongitudinal **S**tudies on **A**ging

Big Data, Big Analysis:

A Collaborative Modeling Framework for Multi-study Replication

Andriy V. Koval

University of Victoria

William H. Beasley

University of Oklahoma

Andrea Piccinin

University of Victoria

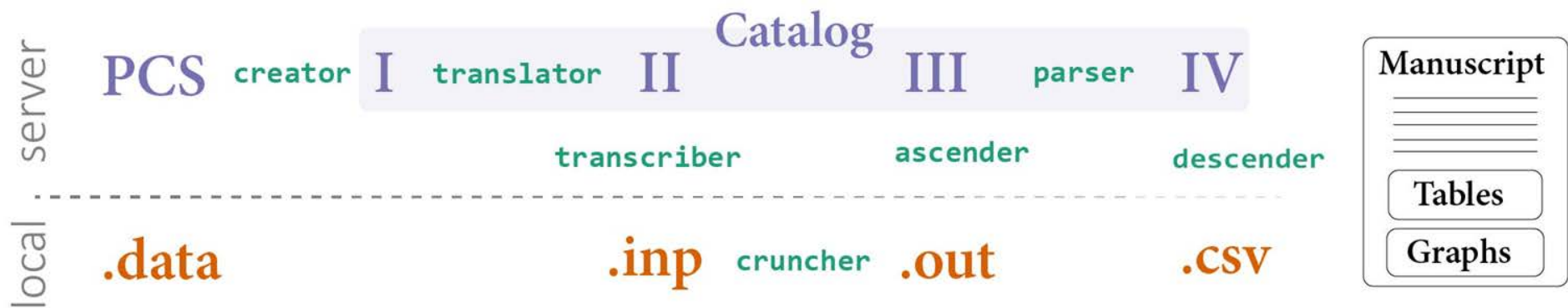
Graciela Muniz-Terrera

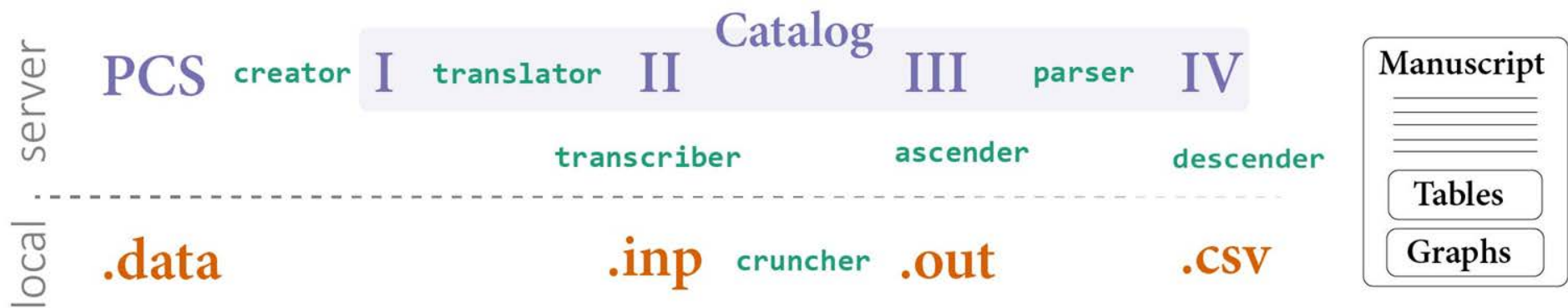
University of Edinburgh

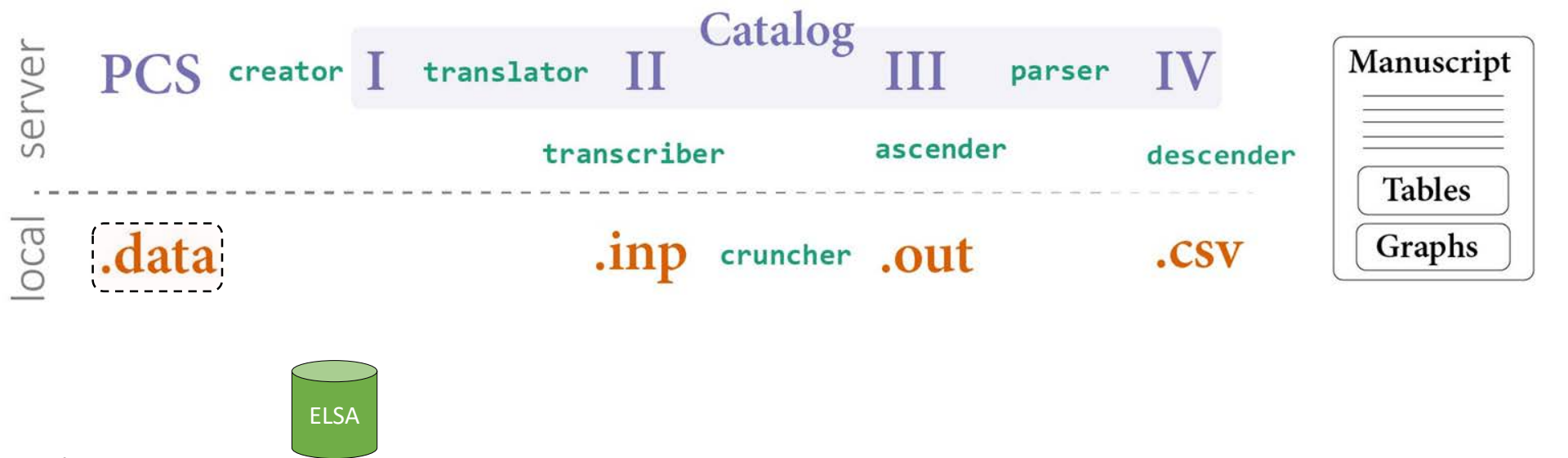
Scott Hofer

University of Victoria

Convention of Canadian Psychological Association | Victoria, BC | June 10, 2016

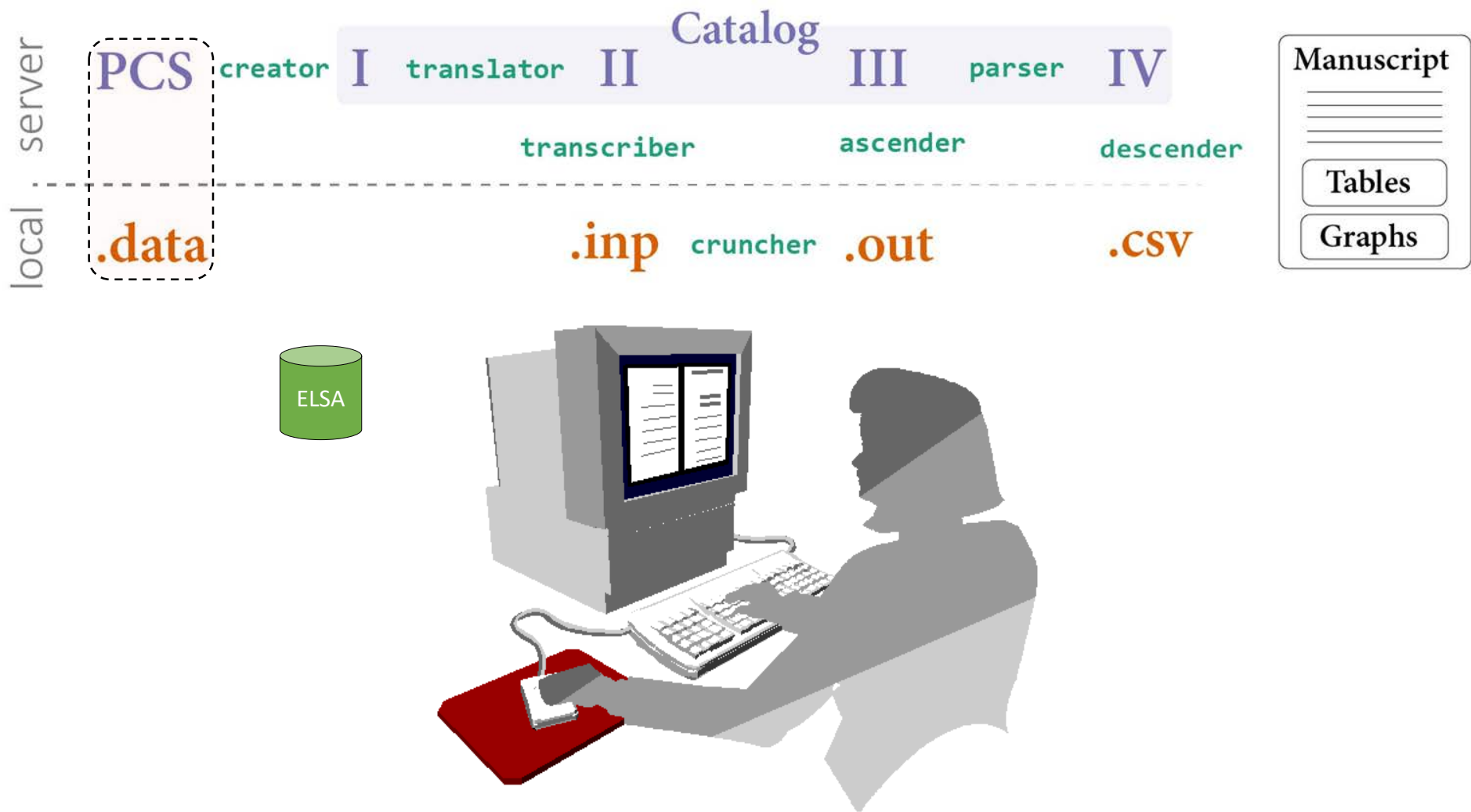






	id	year_bl	age_bl	year_born	male_bl	edu_bl	height_cm_bl	diabetes_bl	cardio_bl	smoke_bl	age_t1	age_t2	age_t3	age_t4	age_t5	age_t6	animals_t1	animals_t2	animals_t3	animals_t4	animals_t5	animals
1	103712	2002	55	1947	0	4	172.20	1	0	0	55	57	59	61	63	65	18	24	15	16	23	NA
2	103713	2002	71	1931	1	3	NA	0	0	0	71	73	75	NA	NA	NA	10	9	8	NA	NA	NA
3	103714	2002	51	1950	0	4	169.50	0	0	0	51	53	55	57	59	61	33	27	19	28	31	NA

	id	wave	year_born	years_since_bl	year_bl	year	age_bl	age	male_bl	edu_bl	height_cm_bl	diabetes_bl	cardio_bl	smoke_bl	fev	fvc	pef	grip	gait	word_recall_im	word_recall_de	animals
1	103712	1	1947	0	2002	2002	55	55	0	4	172.20	1	0	0	NA	NA	NA	NA	NA	6	6	18
2	103712	2	1947	2	2002	2004	55	57	0	4	172.20	1	0	0	2.99	2.99	4.99	26.833333	NA	6	6	24
3	103712	3	1947	4	2002	2006	55	59	0	4	172.20	1	0	0	NA	NA	NA	NA	NA	10	8	15
4	103712	4	1947	6	2002	2008	55	61	0	4	172.20	1	0	0	2.58	2.58	3.78	21.333333	0.687679112	7	7	16
5	103712	5	1947	8	2002	2010	55	63	0	4	172.20	1	0	0	NA	NA	NA	NA	1.105990767	7	6	23
6	103712	6	1947	10	2002	2012	55	65	0	4	172.20	1	0	0	NA	NA	NA	25.500000	1.019108295	6	6	NA
7	103713	1	1931	0	2002	2002	71	71	1	3	NA	0	0	0	NA	NA	NA	NA	0.108572721	5	1	10
8	103713	2	1931	2	2002	2004	71	73	1	3	NA	0	0	0	NA	NA	3.62	17.166667	0.096793711	3	4	9
9	103713	3	1931	4	2002	2006	71	75	1	3	NA	0	0	0	NA	NA	NA	NA	NA	4	2	8
10	103714	1	1950	0	2002	2002	51	51	0	4	169.50	0	0	0	NA	NA	NA	NA	NA	8	7	33



server

local

PCS

creator

I

translator

II

Catalog

III

parser

IV

transcriber

ascender

descender

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.inp

cruncher

.out

.csv

Manuscript

Tables

Graphs

Domains

- visual discrimination
- perceptual speed
- fluency
- attention
- fluid reasoning
- mental status
- executive function
- working memory
- short-term memory
- semantic memory
- episodic memory
- verbal comprehension

Cognitive measures

	eas	elsa	hrs	iise	lasa	map	nuage	octo	satsa
line orientation						line, 24			
picture completion				piccomp, 8					
figure identification									fig_id, 12
number comparison						numb_comp, 23			
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substitution	symbol, 38			symbol, 8	arab, 8	symbol, 24		symbol, 22	symbol, 18
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IPSS spatial acuity				piccomp, 8					
matrices					raven, 8	matix, 24			
rotations									rotate, 10
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tics			tcs, 18						
switching	tratio, 29								
digit ordering						digit_o, 24			
digit span backward						digit_b, 24			
digit span total	digit_tot, 28							digit_b, 21	digit_b, 14
figure memory									fig_mem, 10
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prose recall immediate						history_lm, 24			
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boston naming test	bnt, 20					bnt, 23			
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synonyms								synon, 8	synon, 18
vocabulary	waivoc, 20								
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word list recognition						word_rec, 20			
information	info, 20			wang, 8				info, 8	info, 18
logical memory delayed						logic_de, 24			
memory in reality								mir, 18	
prose recall delayed						history_de, 24			
prose recall total	logic_tot, 19								
auditory comprehension						ideas, 24			

server

local

PCS

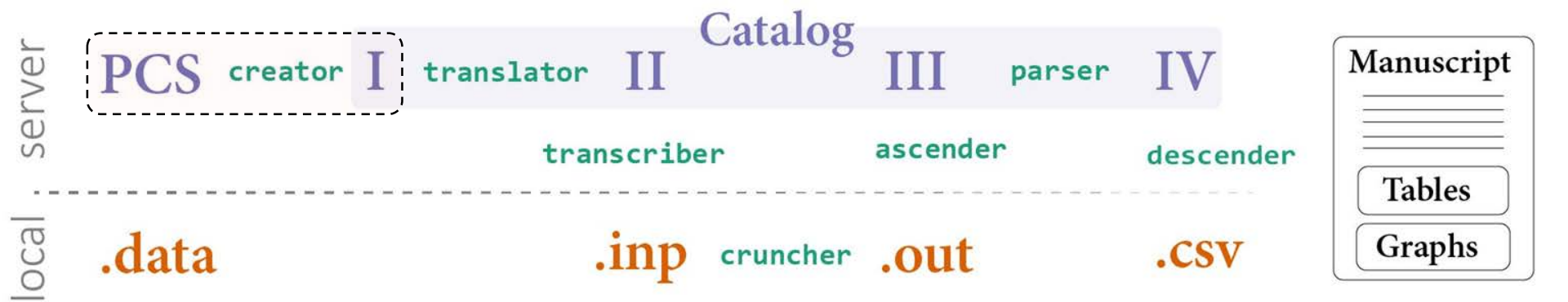
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Domains

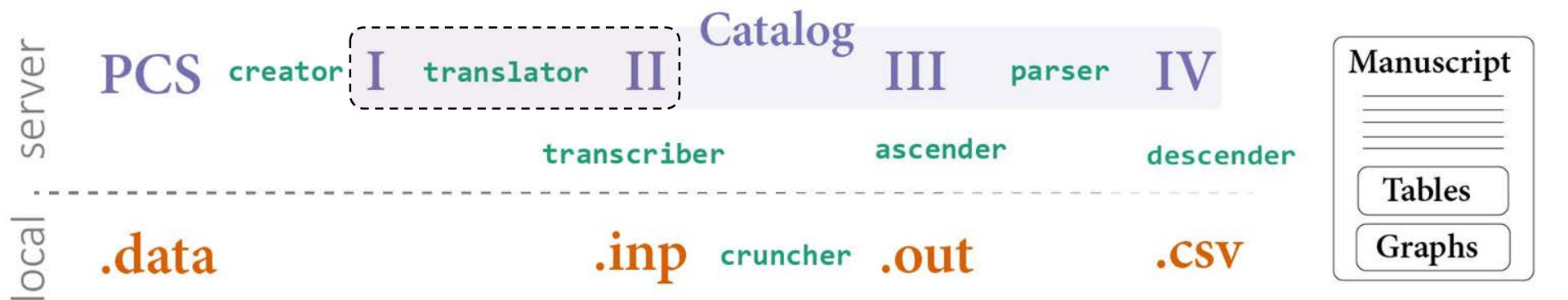
- visual discrimination
- perceptual speed
- fluency
- attention
- fluid reasoning
- mental status
- executive function
- working memory
- short-term memory
- semantic memory
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- verbal comprehension

Cognitive measures

	eas	elsa	hrs	ilse	lasa	map	nuage	octo	satsa
line orientation						line, 24			
picture completion				piccomp, 8					
figure identification									fg_id, 12
number comparison						num_comp, 23			
perceptual speed								psf, 8	
substitution	symbol, 30			symbol, 8	letter, 6	symbol, 24		symbol, 22	symbol, 18
categories	cat, 20					cat, 25			
f-s-s phonemic words	fas, 21								
fluency		fluency, 2		fluency, 7					
digit span forward						digit_f, 24		digit_f, 24	digit_f, 14
serial7			serial7, 16						
analogies									analogies, 18
block design	block, 27			block, 8				block, 26	block, 12
figure logic								fig_logic, 18	
IPSS spatial ability				piccomp, 8					
matrices					raven, 6	matrx, 24			
rotations									rotate, 10
mini mental state exam	mmse, 20					mmse, 23	mmse, 18	mmse, 8	mmse, 18
tics			tics, 18						
switching	trailsb, 29								
digit ordering						digit_o, 24			
digit span backward						digit_b, 24		digit_b, 24	digit_b, 14
digit span total	digit_tot, 29								fig_mem, 10
figure memory									
logical memory immediate						logic_im, 23			
prose recall immediate						bstory_im, 24		prose_im, 25	
word list immediate		word_im, 8	word_im, 18		word_im, 6	word_im, 24			
boston naming test	bnt, 20					bnt, 23			
reading						nart, 23			
synonyms								synon, 8	synon, 18
vocabulary	vaisvoc, 20								
word list delayed		word_de, 16	word_de, 36			word_de, 24			
word list recognition						word_rec, 20			
Information	info, 20			waistg, 8				info, 8	info, 18
logical memory delayed						logic_de, 24			
memory in reality								mir, 18	
prose recall delayed						bstory_de, 24			
prose recall total	logic_tot, 19								
auditory comprehension						ideas, 24			



	id ↕	year_bl ↕	age_bl ↕	year_born ↕	male_bl ↕	edu_bl ↕	height_cm_bl ↕	diabetes_bl ↕	cardio_bl ↕	smoke_bl ↕	age_t1 ↕	age_t2 ↕	age_t3 ↕	age_t4 ↕	age_t5 ↕	age_t6 ↕	animals_t1 ↕	animals_t2 ↕	animals_t3 ↕	animals_t4 ↕	animals_t5 ↕	anima
1	103712	2002	55	1947	0	4	172.20	1	0	0	55	57	59	61	63	65	18	24	15	16	23	NA
2	103713	2002	71	1931	1	3	NA	0	0	0	71	73	75	NA	NA	NA	10	9	8	NA	NA	NA
3	103714	2002	51	1950	0	4	169.50	0	0	0	51	53	55	57	59	61	33	27	19	28	31	NA



$$\begin{aligned} o=\text{Physical} \beta_{0i} &= {}_p\gamma_{00} + {}_p\Gamma_{0k}(\text{CovSet}) + {}_p\boldsymbol{u}_{0i} \\ o=\text{Physical} \beta_{1i} &= {}_p\gamma_{10} + {}_p\Gamma_{1k}(\text{CovSet}) + {}_p\boldsymbol{u}_{1i} \\ o.y_{it} &= {}_o\beta_{0i} + {}_o\beta_{1i}(\text{Time}_{it}) + {}_o\boldsymbol{\varepsilon}_{it} \\ o=\text{Cognitive} \beta_{1i} &= {}_c\gamma_{10} + {}_c\Gamma_{1k}(\text{CovSet}) + {}_c\boldsymbol{u}_{1i} \\ o=\text{Cognitive} \beta_{0i} &= {}_c\gamma_{00} + {}_c\Gamma_{0k}(\text{CovSet}) + {}_c\boldsymbol{u}_{0i} \end{aligned}$$

Fixed Effects Random Effects Residuals

Physical Intercept ${}_p\gamma_{00}$ ${}_p\gamma_{01}$ ${}_p\gamma_{02}$ \dots ${}_p\gamma_{0k}$ ${}_{pp}\tau_{00}$ ${}_{pp}\tau_{01}$ ${}_{pc}\tau_{01}$ ${}_{pc}\tau_{00}$

Physical Slope ${}_p\gamma_{10}$ ${}_p\gamma_{11}$ ${}_p\gamma_{12}$ \dots ${}_p\gamma_{1k}$ ${}_{pp}\tau_{11}$ ${}_{pc}\tau_{11}$ ${}_{pc}\tau_{10}$

Cognitive Slope ${}_c\gamma_{10}$ ${}_c\gamma_{11}$ ${}_c\gamma_{12}$ \dots ${}_c\gamma_{1k}$ ${}_{cc}\tau_{11}$ ${}_{cc}\tau_{10}$

Cognitive Intercept ${}_c\gamma_{00}$ ${}_c\gamma_{01}$ ${}_c\gamma_{02}$ \dots ${}_c\gamma_{0k}$ ${}_{cc}\tau_{00}$

${}_p\sigma^2$ ${}_{pc}\sigma^2$ ${}_c\sigma^2$

	id	year_bl	age_bl	year_born	male_bl	edu_bl	height_cm_bl	diabetes_bl	cardio_bl	smoke_bl	age_t1	age_t2	age_t3	age_t4	age_t5	age_t6	animals_t1	animals_t2	animals_t3	animals_t4	animals_t5	anima
1	103712	2002	55	1947	0	4	172.20	1	0	0	55	57	59	61	63	65	18	24	15	16	23	NA
2	103713	2002	71	1931	1	3	NA	0	0	0	71	73	75	NA	NA	NA	10	9	8	NA	NA	NA
3	103714	2002	51	1950	0	4	169.50	0	0	0	51	53	55	57	59	61	33	27	19	28	31	NA

.data

.inp

cruncher

.out

.CSV

$$_{o=\text{Physical}}\beta_{0i} = {}_p\gamma_{00} + {}_p\Gamma_{0k}(\text{CovSet}) + {}_p u_{0i}$$
$$_{o=\text{Physical}}\beta_{1i} = {}_p\gamma_{10} + {}_p\Gamma_{1k}(\text{CovSet}) + {}_p u_{1i}$$
$${}_oy_{ti} = {}_o\beta_{0i} + {}_o\beta_{1i}(Time_{ti}) + {}_o\varepsilon_{ti}$$
$$_{o=\text{Cognitive}} \beta_{li} = {}_c \gamma_{10} + {}_c \Gamma_{1k}(\text{CovSet}) + {}_c u_{li}$$
$$_{o=\text{Cognitive}} \beta_{0i} = {}_c \gamma_{00} + {}_c \Gamma_{0k}(\text{CovSet}) + {}_c u_{0i}$$

Fixed Effects

Random Effects

Residuals

Physical Intercept

$${}_p\gamma_{00} \quad {}_p\gamma_{01} \quad {}_p\gamma_{02} \cdots {}_p\gamma_{0k}$$
$$pp\tau_{00} \quad pp\tau_{01} \quad pc\tau_{01} \quad pc\tau_{00}$$
 σ^2

Physical Slope

$${}_p\gamma_{10} \quad {}_p\gamma_{11} \quad {}_p\gamma_{12} \cdots {}_p\gamma_{1k}$$
$$pp\tau_{11} \quad pc\tau_{11} \quad pc\tau_{10}$$
 p°

Cognitive Slope

$${}_c\gamma_{10} \quad {}_c\gamma_{11} \quad {}_c\gamma_{12} \quad \cdots \quad {}_c\gamma_{1k}$$
$${}_{cc}\tau_{11} \quad {}_{cc}\tau_{10}$$

Cognitive Intercept

$${}_c\gamma_{00} \quad {}_c\gamma_{01} \quad {}_c\gamma_{02} \cdots {}_c\gamma_{0k}$$
 ${}_{cc}\tau_{00}$

	id	year_bl	age_bl	year_born	male_bl	edu_bl	height_cm_bl	diabetes_bl	cardio_bl	smoke_bl	age_t1	age_t2	age_t3	age_t4	age_t5	age_t6	animals_t1	animals_t2	animals_t3	animals_t4	animals_t5	animals_t6
1	103712	2002	55	1947	0	4	172.20	1	0	0	55	57	59	61	63	65	18	24	15	16	23	NA
2	103713	2002	71	1931	1	3	NA	0	0	0	71	73	75	NA	NA	NA	10	9	8	NA	NA	NA
3	103714	2002	51	1950	0	4	169.50	0	0	0	51	53	55	57	59	61	33	27	19	28	31	NA

	id	year_bl	age_bl	year_born	male_bl	edu_bl	height_cm_bl	diabetes_bl	cardio_bl	smoke_bl	age_t1	age_t2	age_t3	age_t4	age_t5	age_t6	animals_t1	animals_t2	animals_t3	animals_t4	animals_t5	animals_t6
1	103712	2002	55	1947	0	4	172.20	1	0	0	55	57	59	61	63	65	18	24	15	16	23	NA
2	103713	2002	71	1931	1	3	NA	0	0	0	71	73	75	NA	NA	NA	10	9	8	NA	NA	NA
3	103714	2002	51	1950	0	4	169.50	0	0	0	51	53	55	57	59	61	33	27	19	28	31	NA

Mplus - [0000007-b1-elsa-fev-categories-female-eh.out]

File Edit View Mplus Plot Diagram Window Help

Script produced from the prototype in ./sandbox/syntax-creator/
File = wide.dat;
VARIABLES are
Names are
id year_b1 age_b1 year_born male_b1 edu_b1 height_cm_b1 diabetes_b1 cardio_b1
smoke_b1 age_t1 age_t2 age_t3 age_t4 age_t5 age_t6 animals_t1 animals_t2
animals_t3 animals_t4 animals_t5 animals_t6 fev_t1 fev_t2 fev_t3 fev_t4 fev_t5
fev_t6 fev_t7 fev_t8 gait_t1 gait_t2 gait_t3 gait_t4 gait_t5
gait_t6 gait_t7 gait_t8 grip_t1 grip_t2 grip_t3 grip_t4 grip_t5 grip_t6
perf_t1 perf_t2 perf_t3 perf_t4 perf_t5 perf_t6 word_recall_de_t1 word_recall_de_t2
word_recall_de_t3 word_recall_de_t4 word_recall_de_t5 word_recall_de_t6
word_recall_im_t1 word_recall_im_t2 word_recall_im_t3 word_recall_im_t4
word_recall_im_t5 word_recall_im_t6 year_t1 year_t2 year_t3 year_t4 year_t5
year_t6 years_since_b1_t1 years_since_b1_t2 years_since_b1_t3 years_since_b1_t4
years_since_b1_t5 years_since_b1_t6
Missing are all (-9999);
USEVARS are
!define the variables used in the analysis
! covariates used in the model
age_b1 edu_b1 height_cm_b1
!estimated time points
time2
time4
!modelled time points of process (A)
a2
a4
!modelled time points of process (B)
b2
b4
!TSOCRES are
!estimated time points
time2
time4;
!OBSERVATIONS are
!select a subset of observations
male_b1 EQ 0
!and
!dementia_ever NE 1
;
!DEFINITE:
! assign variables to the process (A)
a2=fev_t2;
a4=fev_t4;
! assign variables to the process (B)
b2=animals_t2;
b4=animals_t4;
!assign variables to time points
time2=years_since_b1_t2;
time4=years_since_b1_t4;
;
!TSOCRES
Ready

ANALYSIS:
TYPE = RANDOM;
COVERAGE=.00;
MODEL:
!first-level equation
! assign process (A) to time points
ia sa | a2 AT time2;
ia sa | a4 AT time4;
! assign process (B) to time points
ib sb | b2 AT time2;
ib sb | b4 AT time4;
!variance of the first-level terms
ia (v ia);
sa (v sa);
ib (v ib);
sb (v sb);
!covariance among first-level terms
ia WITH sa (c ia_sb);
ia WITH ib (c ia_ib);
ia WITH sb (c ia_sb);
sa WITH ib (c sa_ib);
sa WITH sb (c sa_sb);
ib WITH sb (c ia_sb);
!second-level equation
ia sa ib sb ON age_b1 edu_b1 height_cm_b1;
!residual covariance of process (A)
a2 (res a);
a4 (res a);
!residual covariance of process (B)
b2 (res b);
b4 (res b);
!Paired covariances constrained to be equal across t
a2 pwith b2 (res_cov);
a4 pwith b4 (res_cov);
MODEL CONSTRAINT:
!assigns labels to new parameters;
NEW r_iaib;
NEW r_sasb;
NEW r_res_ab;
!compute confidence intervals for correlation coefficients;
r_iaib = c_iaib/((v ia**0.5)*(v ib**0.5));
r_sasb = c_sasb/((v sa**0.5)*(v sb**0.5));
r_res_ab = res_cov/((res a**0.5)*(res b**0.5));
OUTPUT: sampstat interval;
PLOT: Type is Plot1 Plot2 Plot3;

Mplus - [0000007-b1-elsa-fev-categories-female-eh.out]

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MODEL FIT INFORMATION

Number of Free Parameters 27

Loglikelihood

H0 Value -26716.001

H0 Scaling Correction Factor 1.9215

Information Criteria

Akaike (AIC) 53486.002

Bayesian (BIC) 53658.317

Sample-Size Adjusted BIC 53572.522
(n* = (n + 2) / 24)

MODEL RESULTS

		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
IA	ON				
	AGE_BL	-0.023	0.001	-20.819	0.000
	EDU_BL	-0.016	0.004	-3.732	0.000
	HEIGHT_CM	0.025	0.002	15.963	0.000
SA	ON				
	AGE_BL	-0.001	0.000	-2.325	0.020
	EDU_BL	-0.001	0.001	-1.310	0.190
	HEIGHT_CM	0.000	0.000	0.639	0.523
IB	ON				
	AGE_BL	-0.123	0.014	-8.820	0.000
	EDU_BL	-0.810	0.064	-12.740	0.000
	HEIGHT_CM	0.102	0.020	5.213	0.000
SB	ON				
	AGE_BL	-0.017	0.003	-5.787	0.000
	EDU_BL	-0.010	0.013	-0.776	0.438
	HEIGHT_CM	-0.004	0.004	-0.942	0.346
IA	WITH				
	SA	0.000	0.009	0.039	0.968
	IB	0.143	0.065	2.189	0.029
	SB	0.000	0.009	0.039	0.968
SA	WITH				
	IB	-0.009	0.017	-0.498	0.618
	SB	0.000	0.003	0.008	0.993
IB	WITH				
	SB	0.000	0.009	0.039	0.968
A2	WITH				
	B2	-0.005	0.031	-0.177	0.860
A4	WITH				
	B4	-0.005	0.031	-0.177	0.860

Intercepts		0.000	0.000	999.000	999.000		
A2		0.000	0.000	999.000	999.000		
A4		0.000	0.000	999.000	999.000		
B2		0.000	0.000	999.000	999.000		
B4		0.000	0.000	999.000	999.000		
IA		-0.238	0.277	-0.861	0.389		
IB		-0.040	0.059	-0.473	0.301		
IS		15.558	3.490	4.458	0.000		
IS		1.696	0.714	2.367	0.018		
Residual Variances		0.051	0.016	3.215	0.001		
A2		0.051	0.016	3.215	0.001		
B2		16.938	0.783	21.441	0.000		
B4		16.938	0.783	21.641	0.000		
IA		0.088	0.042	2.068	0.039		
IB		0.003	0.002	1.486	0.137		
IS		15.232	0.837	17.774	0.000		
IS		0.070	0.041	1.692	0.091		
New/Additional Parameters							
R_IAIB		0.124	0.046	2.684	0.007		
R_SASB		0.000	0.000	0.000	0.993		
R_RES_AB		-0.006	0.034	-0.174	0.862		
QUALITY OF NUMERICAL RESULTS							
Condition Number for the Information Matrix (ratio of smallest to largest eigenvalue)				0.360E-09			
CONFIDENCE INTERVALS OF MODEL RESULTS							
		Lower .5%	Lower 2.5%	Estimate	Upper .5%	Upper 2.5%	Upper .95%
IA	AGE_BL	-0.026	-0.025	-0.025	-0.023	-0.021	-0.021
	EDU_BL	-0.028	-0.025	-0.024	-0.016	-0.009	-0.008
	HEIGHT_CM	0.001	0.002	0.022	0.023	0.027	0.028
SA	AGE_BL	-0.001	-0.001	-0.001	-0.001	0.000	0.000
	EDU_BL	-0.004	-0.003	-0.003	-0.002	0.000	0.001
	HEIGHT_CM	-0.001	0.000	0.000	0.000	0.001	0.001
IB	AGE_BL	-0.139	-0.130	-0.146	-0.123	-0.100	-0.093
	EDU_BL	-0.913	-0.814	-0.814	-0.810	-0.705	-0.685
	HEIGHT_CM	0.052	0.044	0.070	0.102	0.134	0.146
SB	AGE_BL	-0.025	-0.023	-0.022	-0.017	-0.012	-0.011
	EDU_BL	-0.043	-0.035	-0.031	-0.010	0.011	0.015
	HEIGHT_CM	-0.014	-0.012	-0.010	-0.004	0.003	0.004
TA	AGE_BL	-0.022	-0.017	-0.014	0.000	0.015	0.017
	EDU_BL	-0.023	-0.013	0.006	0.143	0.251	0.312
	HEIGHT_CM	-0.022	-0.017	-0.014	0.000	0.013	0.023
SA	IB WITH	-0.053	-0.043	-0.037	-0.009	0.020	0.025
	SB	-0.009	-0.006	-0.005	0.000	0.006	0.007
IB	SA WITH	-0.022	-0.017	-0.014	0.000	0.015	0.017
A2	B2 WITH	-0.084	-0.066	-0.056	-0.005	0.045	0.055
A4	B4 WITH	-0.084	-0.066	-0.056	-0.005	0.045	0.055
Intercepts		0.000	0.000	0.000	0.000	0.000	0.000
A2		0.000	0.000	0.000	0.000	0.000	0.000
A4		0.000	0.000	0.000	0.000	0.000	0.000
B2		0.000	0.000	0.000	0.000	0.000	0.000
B4		0.000	0.000	0.000	0.000	0.000	0.000
IA		-0.951	-0.781	-0.693	-0.238	0.217	0.304
IB		-0.193	-0.156	-0.138	-0.040	0.058	0.076
IS		6.568	8.717	9.816	15.558	21.299	24.548
IS		-0.149	0.292	0.517	1.696	2.874	3.100
Residual Variances		0.010	0.020	0.025	0.051	0.076	0.081
A2		0.010	0.020	0.025	0.051	0.076	0.081
B2		14.922	15.404	15.650	16.938	18.225	18.472
B4		14.922	15.404	15.650	16.938	18.225	18.472
IA		-0.022	0.005	0.018	0.008	0.015	0.017
IB		-0.002	-0.001	0.000	0.003	0.007	0.009
IS		13.025	13.552	13.822	15.232	16.442	17.193
IS		-0.037	-0.011	0.002	0.070	0.138	0.151
New/Additional Parameters							
R_IAIB		0.005	0.033	0.048	0.124	0.200	0.243
R_SASB		-0.573	-0.436	-0.365	0.002	0.369	0.577
R_RES_AB		-0.092	-0.072	-0.061	-0.006	0.049	0.080

