

1 Supplementary Information

2 **Table S1.** Fixed effect estimates (with standard errors in parentheses) from the full random intercept
 3 and random slope model for maze time in both maze A and B

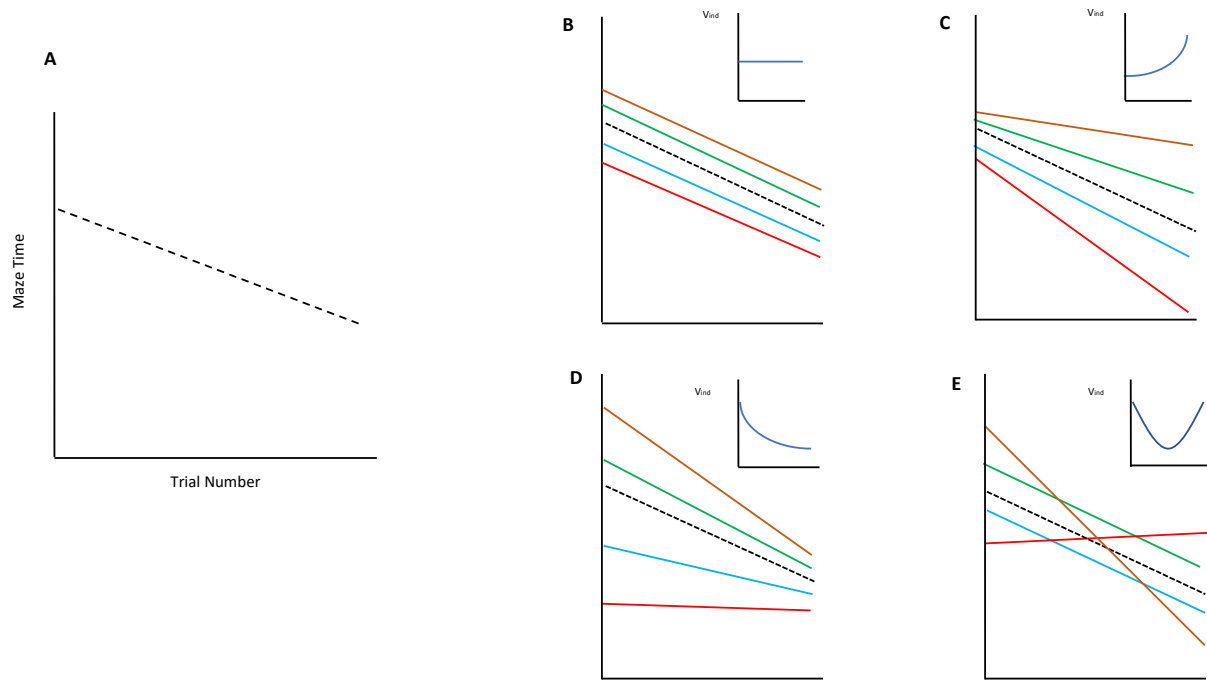
Maze	Fixed effect	Effect size (SE)	DF	F	P
A	Intercept	0.140 (0.117)	1, 114.6	1.369	0.075
	Trial	-0.043 (0.014)	1, 59.8	10.140	0.003
	Maze position (top)	0.105 (0.061)	1, 600.3	2.987	0.085
	Order	-0.025 (0.015)	1, 635.1	3.189	0.096
B	Intercept	0.172 (0.140)	1, 107.7	2.552	0.111
	Trial	0.014 (0.014)	1, 53.6	1.193	0.301
	Maze position (top)	0.066 (0.070)	1, 540.4	0.892	0.345
	Order	-0.030 (0.020)	1, 565.8	2.760	0.116

4

5 **Table S2.** Fixed effect estimates (with standard errors in parentheses) from the full random intercept
 6 and random slope model for relative area from the open field trials (OFT).

Model	Fixed effect	Effect size (SE)	DF	F	P
OFT	Intercept	0.229 (0.451)	1, 159	0.003	0.613
	Trial	-0.262 (0.066)	1, 116.8	15.710	< 0.001
	Time	0.000 (0.000)	1, 150.3	0.003	0.953

7



8

9 **Fig. S1.** Characterising individual variation in learning performance. Main panel (A) shows an average
 10 (black dashed line) decrease in maze time with trial number from 1 to 11 consistent with learning.
 11 Inset panels show how individual trajectories may vary around this because of differences in reaction
 12 norm intercepts (B) and or slopes (C-E). Where slopes vary (C-E), a corollary of this is that the
 13 among-individual variance (V_{ind}) in maze time will change across trials. This could potentially
 14 increase (C) or decrease (D) monotonically, or there could be an intermediate trial number at which
 15 variance is minimised (E) or maximised (not shown). Where reaction norms tend to cross a lot within
 16 the range of trial numbers explored (E), this will result in low (and potentially negative) among-
 17 individual correlations between early and late trials.

18

19 **Table S3:** Character state representation of among-individual correlation structure between trial specific *maze time* (both mazes) and *relative area*.

20

21 Table 1 in the main text presents the estimated among individual (**ID**) covariance matrix of reaction norm (RN) intercepts and slopes for *Maze time_A*, *Maze*
22 *time_B* and *relative area* (intercept only). Assuming the assumption of linear reaction norms hold true this can be transformed to the corresponding ‘character
23 state’ (CS) among-individual covariance matrix of trial specific maze times and *relative area* (designated **ID_{CS}**).

24 For a single trait (e.g. *Maze time_A*), $\mathbf{ID}_{CS} = \mathbf{Q} \cdot \mathbf{ID}_{RN} \cdot \mathbf{Q}^T$ (following e.g. equation 5.8 in Roff and Wilson 2015), where \mathbf{ID}_{RN} is the 2x2 covariance matrix of
25 reaction norm (RN) intercepts and slopes, \mathbf{Q}^T is the transpose of matrix \mathbf{Q} , and \mathbf{Q} itself contains the values of the covariate (trial number) at which we wish
26 to evaluate \mathbf{ID}_{CS} . Where we want \mathbf{ID}_{CS} to be an 11x11 matrix containing the among-individual variance in maze time at each trial number (1-11) on the

27 diagonal, and the covariance between each pair of trial numbers in the off diagonal elements $\mathbf{Q} =$

$$\begin{bmatrix} 1 & 1 \\ 1 & 2 \\ 1 & 3 \\ 1 & 4 \\ 1 & 5 \\ 1 & 6 \\ 1 & 7 \\ 1 & 8 \\ 1 & 9 \\ 1 & 10 \\ 1 & 11 \end{bmatrix}$$

28

29 Following this, but expanded to the multivariate case, we transformed the estimated covariance matrix (**ID**) formulated under the trivariate model described in
30 the main text (i.e., with individual effects on Maze A and B modelled as first order random regressions of trial number) to the corresponding character state
31 matrix. This was then rescaled to yield point estimates of the among-individual correlation between trial specific performance within- and across-mazes, and

32 between these performances and stress responsiveness. For simplicity we do not similarly attempt to transform estimates of uncertainty, but note that this table
 33 is a mathematical consequence (and transformation) of the statistical estimated presented in Table 1 of the main text (i.e. this is same set of results presented a
 34 different way).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	RA	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
A1																							
A2	0.993																						
A3	0.969	0.991																					
A4	0.925	0.963	0.990																				
A5	0.860	0.914	0.959	0.989																			
A6	0.778	0.846	0.909	0.958	0.990																		
A7	0.684	0.765	0.843	0.910	0.960	0.991																	
A8	0.586	0.678	0.768	0.85	0.917	0.965	0.992																
A9	0.491	0.590	0.690	0.785	0.867	0.929	0.971	0.994															
A10	0.402	0.507	0.615	0.719	0.812	0.888	0.943	0.977	0.995														
A11	0.321	0.430	0.544	0.656	0.759	0.845	0.910	0.955	0.983	0.996													
RA	0.286	0.293	0.295	0.292	0.284	0.269	0.249	0.228	0.205	0.183	0.162												
B1	0.686	0.725	0.757	0.777	0.782	0.770	0.744	0.707	0.665	0.621	0.577	0.024											
B2	0.691	0.733	0.769	0.792	0.800	0.791	0.767	0.733	0.691	0.648	0.605	0.062	0.996										
B3	0.689	0.735	0.774	0.801	0.812	0.806	0.784	0.752	0.712	0.670	0.627	0.101	0.981	0.995									
B4	0.681	0.729	0.771	0.801	0.815	0.812	0.794	0.764	0.726	0.686	0.645	0.140	0.957	0.980	0.995								
B5	0.666	0.716	0.760	0.793	0.810	0.811	0.795	0.768	0.733	0.694	0.655	0.178	0.922	0.955	0.979	0.995							
B6	0.644	0.696	0.742	0.777	0.797	0.801	0.789	0.764	0.732	0.696	0.659	0.214	0.879	0.920	0.954	0.980	0.995						
B7	0.617	0.670	0.717	0.754	0.777	0.784	0.775	0.754	0.724	0.691	0.656	0.246	0.829	0.878	0.921	0.956	0.981	0.995					
B8	0.586	0.639	0.687	0.726	0.752	0.761	0.755	0.737	0.711	0.680	0.648	0.274	0.775	0.831	0.882	0.925	0.959	0.982	0.996				
B9	0.552	0.606	0.655	0.695	0.722	0.734	0.731	0.716	0.693	0.665	0.636	0.299	0.718	0.781	0.838	0.889	0.931	0.963	0.984	0.996			
B10	0.518	0.571	0.620	0.661	0.690	0.704	0.704	0.692	0.672	0.647	0.620	0.319	0.661	0.729	0.793	0.851	0.900	0.939	0.968	0.987	0.997		
B11	0.484	0.536	0.585	0.627	0.657	0.673	0.675	0.666	0.649	0.627	0.602	0.336	0.605	0.678	0.747	0.810	0.866	0.911	0.947	0.972	0.989	0.997	

35

36 **R code for Maze A, Maze B and Relative Area univariate mixed models, and full multivariate mode for all**
37 **traits.**

38 All models were fit using the proprietary package ASRemlR v4 (<https://www.vsni.co.uk/software/asreml/>).

39

```
40 #####
41
42 #load libraries and data
43 library(asreml)
44 library(tidyverse)
45
46 df_maze <- read.csv("Maze_OFT.csv", header=TRUE, na.strings="NA")
47
48
49
50
51 #####
52 #Maze A
53
54 #####
55 # Fit random intercept model for Maze A and extract results#
56
57 asr_approachA <- asreml(App_AS ~ Trial +
58     Order_caught +
59     Maze_position,
60     random = ~ ID,
61     residual = ~ idv(units),
62     data = df_maze,
63     maxiter = 100,
64     na.action = na.method(x="omit", y="omit"))
65
66 #Extract results, check convergence and summarise main results
67 asr_approachA$converge
68 summary(asr_approachA)
69
70 # fixed effect estimates and conditional F tests
71 summary(asr_approachA, coef = TRUE)$coef.fixed
72 wald.asreml(asr_approachA, ssType="conditional", denDF="numeric")
73
74 #Obtain estimated repeatability
75 R<-vpredict (asr_approachA, R~(V1)/(V1+V2) )
76
77 #####
78 # Fit random intercepts model for Maze A with no random effects, for model comparison with full random
79 intercepts model, and perform likelihood ratio test#
80
81 asr_noranA <- asreml(App_AS ~ Trial +
82     Order_caught +
83     Maze_position,
84     residual = ~ units,
85     data = df_maze,
86     maxiter = 100,
87     na.action = na.method(x="omit", y="omit"))
88
89 pchisq(2*(asr_approachA$loglik - asr_noranA$loglik), 1, lower.tail = FALSE)
90
```

```

91
92 #####
93 #Fit random intercepts and random slopes model for Maze A, and extract results#
94
95 asr_A_RR <- asreml(App_AS~ Trial +
96     Order_caught +
97     Maze_position ,
98     random = ~str(~ID + ID:Trial,
99         ~us(2, init = c(1,0.1,1)):id(63)),
100     residual = ~units,
101     data = df_maze,
102     maxiter = 200,
103     na.action = na.method(x="omit", y="omit"))
104
105 #Extract results, check convergence and summarise main results
106
107 asr_A_RR $converge
108 summary (asr_A_RR)
109
110 #Fixed effect estimates and conditional F tests
111 summary(asr_A_RR, coef = TRUE)$coef.fixed
112 wald.asreml(asr_A_RR, ssType="conditional", denDF="numeric")
113
114
115 #Obtain estimated repeatability
116 R<-vpredict (asr_A_RR, R~(V1)/(V1+V4))
117
118 #Log likelihood model comparison between full random slopes and intercepts model and random intercepts only
119 model#
120 pchisq(2*(asr_A_RR$loglik - asr_A_RI$loglik),
121     2, lower.tail = FALSE)
122
123 #####
124 #Fit random intercepts and random slopes model for Maze A with no correlation structure for log likelihood
125 model comparison, and extract results#
126
127 #Obtain estimated correlation for slopes and intercept in Maze A from full random intercepts and slopes model #
128 vpredict(asr_A_RR, cor_is ~ V2/(sqrt(V1)*sqrt(V3)))
129
130
131 #Model with no correlation structure
132 asr_A_RR_idh <- asreml(App_AS~ Trial +
133     Order_caught +
134     Maze_position ,
135     random = ~str(~ID + ID:Trial,
136         ~idh(2, init = c(1,1)):id(63)),
137     residual = ~units,
138     data = df_maze,
139     maxiter = 200,
140     na.action = na.method(x="omit", y="omit"))
141
142 pchisq(2*(asr_A_RR$loglik - asr_A_RR_idh$loglik),
143     2, lower.tail = FALSE)
144
145
146
147 #####
148 #Fit null model and random intercepts model for Maze A with scaled intercept, and extract results#
149
150 #Null model

```

```

151 asr_appA10_null<-asreml(App_AS ~ Trial2 +
152     Order_caught +
153     Maze_position,
154     residual = ~idv(units),
155     data = df_maze,
156     maxiter = 200,
157     na.action = na.method(x="omit", y="omit"))
158
159
160 #Random intercepts model
161 asr_appA10_RI<-asreml(App_AS ~ Trial2 +
162     Order_caught +
163     Maze_position,
164     random=~ID,
165     residual = ~idv(units),
166     data = df_maze,
167     maxiter = 200,
168     na.action = na.method(x="omit", y="omit"))
169
170 #Extract results, check convergence and summarise main results
171 asr_appA10_RI $converge
172 summary(asr_appA10_RI)
173
174 #Fixed effect estimates and conditional F tests
175 summary(asr_appA10_RI, coef = TRUE)$coef.fixed
176 wald.asreml(asr_appA10_RI, ssType = "conditional", denDF = "numeric" )
177
178 #Log likelihood model comparison between random intercepts model and null model#
179 pchisq(2*(asr_appA10_RI$loglik - asr_appA10_null$loglik),
180     2, lower.tail = FALSE)
181
182
183 #####
184 #Fit random intercepts and random slopes model for Maze A with scaled intercept, and extract results#
185
186 asr_appA10_RR <- asreml(App_AS ~ Trial2 +
187     Order_caught +
188     Maze_position ,
189     random = ~str(~ID + ID:Trial2,
190         ~us(2, init = c(1,0.1,1)):id(63)),
191     residual = ~units,
192     data = df_maze,
193     maxiter = 200,
194     na.action = na.method(x="omit", y="omit"))
195
196 #Extract results, check convergence and summarise main results
197
198 asr_appA10_RR$converge
199 summary(asr_appA10_RR)
200
201 #Fixed effect estimates and conditional F tests
202 summary(asr_appA10_RR)$coef.fixed
203 wald.asreml(asr_appA10_RR, ssType="conditional", denDF="numeric")
204
205
206 #Obtain estimated repeatability
207 vpredict(asr_appA10_RR, rep~ V1/(V1+V4))
208
209 #Log likelihood model comparison between full random slopes and intercepts model and random intercepts only
210 model#

```

```

211 pchisq(2*(asr_appA10_RR$loglik - asr_appA10_RI$loglik),
212         2, lower.tail = FALSE)
213
214 #####
215 #Maze B
216
217 #####
218 # Fit random intercept model for Maze B and extract results#
219
220 asr_approachB <- asreml(App_BS ~ Trial +
221                        Order_caught +
222                        Maze_position,
223                        random = ~ ID,
224                        residual = ~ idv(units),
225                        data = df_maze,
226                        maxiter = 100,
227                        na.action = na.method(x="omit", y="omit"))
228
229 #Extract results, check convergence and summarise main results
230 asr_approachB $converge
231 summary(asr_approachB)
232
233 # fixed effect estimates and conditional F tests
234 summary(asr_approachB, coef = TRUE)$coef.fixed
235 wald.asreml(asr_approachB, ssType="conditional", denDF="numeric")
236
237 #Obtain estimated repeatability
238 R<-vpredict (asr_approachB, R~(V1)/(V1+V2) )
239
240 #####
241 # Fit random intercepts model for Maze B with no random effects, for model comparison with full random
242 intercepts model, and perform likelihood ratio test#
243
244 asr_noranB <- asreml(App_BS ~ Trial +
245                    Order_caught +
246                    Maze_position,
247                    residual = ~ idv(units),
248                    data = df_maze,
249                    maxiter = 100,
250                    na.action = na.method(x="omit", y="omit"))
251
252 pchisq(2*(asr_approachB$loglik - asr_noranB$loglik), 1, lower.tail = FALSE)
253
254
255 #####
256 #Fit random intercepts and random slopes model for Maze B, and extract results#
257
258 asr_B_RR <- asreml(App_BS ~ Trial +
259                  Order_caught +
260                  Maze_position ,
261                  random = ~str(~ID + ID:Trial,
262                               ~us(2, init = c(1,0.1,1)):id(55)),
263                  residual =~units,
264                  data = df_maze,
265                  maxiter = 200,
266                  na.action = na.method(x="omit", y="omit"))
267
268 #Extract results, check convergence and summarise main results
269 asr_B_RR $converge
270 summary (asr_B_RR)

```



```

271
272 #Fixed effect estimates and conditional F tests
273 summary(asr_B_RR, coef = TRUE)$coef.fixed
274 wald.asreml(asr_B_RR, ssType="conditional", denDF="numeric")
275
276
277 #Obtain estimated repeatability
278 R<-vpredict (asr_B_RR, R~(V1)/(V1+V4))
279
280 #Log likelihood model comparison between full random slopes and intercepts model and random intercepts only
281 model#
282 pchisq(2*(asr_B_RR$loglik - asr_B_RI$loglik),
283       2, lower.tail = FALSE)
284
285
286 #####
287 #Fit random intercepts and random slopes model for Maze B with no correlation structure for log likelihood
288 model comparison, and extract results#
289
290 #Obtain estimated correlation for slopes and intercept in Maze B from full random intercepts and slopes model #
291 vpredict(asr_B_RR, cor_is ~ V2/(sqrt(V1)*sqrt(V3)))
292
293
294 #Model with no correlation structure
295 asr_B_idh <- asreml(App_BS~ Trial +
296                   Order_caught +
297                   Maze_position ,
298                   random = ~str(~ID + ID:Trial,
299                                ~idh(2, init = c(1,1)):id(55)),
300                   residual = ~units,
301                   data = df_maze,
302                   maxiter = 200,
303                   na.action = na.method(x="omit", y="omit"))
304
305
306 pchisq(2*(asr_B_RR$loglik - asr_B_idh$loglik),
307       2, lower.tail = FALSE)
308
309
310
311 #####
312 #Fit null model and random intercepts model for Maze B with scaled intercept, and extract results#
313
314 #Null model
315 asr_appB10_null<-asreml(App_BS ~ Trial2 +
316                          Order_caught +
317                          Maze_position,
318                          residual = ~idv(units),
319                          data = df_maze,
320                          maxiter = 200,
321                          na.action = na.method(x="omit", y="omit"))
322
323 #Random intercepts model
324 asr_appB10_RI<-asreml(App_BS ~ Trial2 +
325                       Order_caught +
326                       Maze_position,
327                       random=~ID,
328                       residual = ~idv(units),
329                       data = df_maze,
330                       maxiter = 200,

```

```

331         na.action = na.method(x="omit", y="omit"))
332
333 #Extract results, check convergence and summarise main results
334 asr_appB10_RI $converge
335 summary(asr_appB10_RI)
336
337 #Fixed effect estimates and conditional F tests
338 summary(asr_appB10_RI, coef = TRUE)$coef.fixed
339 wald.asreml(asr_appB10_RI, ssType = "conditional", denDF = "numeric" )
340
341 #Log likelihood model comparison between random intercepts model and null model#
342 pchisq(2*(asr_appB10_RI$loglik - asr_appB10_null$loglik),
343       2, lower.tail = FALSE)
344
345
346 #####
347 #Fit random intercepts and random slopes model for Maze B with scaled intercept, and extract results#
348
349 asr_appB10_RR <- asreml(App_BS ~ Trial2 +
350                       Order_caught +
351                       Maze_position ,
352                       random = ~str(~ID + ID:Trial2,
353                                     ~us(2, init = c(1,0.1,1)):id(55)),
354                       residual = ~units,
355                       data = df_maze,
356                       maxiter = 200,
357                       na.action = na.method(x="omit", y="omit"))
358
359 #Extract results, check convergence and summarise main results
360
361 asr_appB10_RR$converge
362 summary(asr_appB10_RR)
363
364 #Fixed effect estimates and conditional F tests
365 summary(asr_appB10_RR)$coef.fixed
366 wald.asreml(asr_appB10_RR, ssType="conditional", denDF="numeric")
367
368
369 #Obtain estimated repeatability
370 vpredict(asr_appB10_RR, rep~ V1/(V1+V4))
371
372 #Log likelihood model comparison between full random slopes and intercepts model and random intercepts only
373 model#
374 pchisq(2*(asr_appB10_RR$loglik - asr_appB10_RI$loglik),
375       2, lower.tail = FALSE)
376
377
378
379 #####
380 #OFT – Relative Area
381
382 #Fit null model and random intercepts model for Relative Area, and extract results#
383
384 #Null model
385 asr_noranRelArea <- asreml(relAreaS ~ Trial,
386                           residual = ~ idv(units),
387                           data = df_maze,
388                           maxiter = 100,
389                           na.action = na.method(x="omit", y="omit"))
390

```

```

391 #Random intercepts model
392 asr_RelArea <- asreml(relAreaS ~ Trial +
393     TimeMins,
394     random =~ ID,
395     residual =~ units,
396     data = df_maze,
397     maxiter = 200,
398     na.action = na.method(x="omit", y="omit"))
399
400 #Extract results, check convergence and summarise main results
401 asr_RelArea $converge
402 summary(asr_RelArea)
403
404 #Fixed effect estimates and conditional F tests
405 summary(asr_RelArea, coef = TRUE)$coef.fixed
406 wald.asreml(asr_RelArea, ssType = "conditional", denDF = "numeric" )
407
408 #Log likelihood model comparison between random intercepts model and null model#
409 pchisq(2*( asr_RelArea $loglik - asr_noranRelArea$loglik),
410     1, lower.tail = FALSE)
411
412
413 #####
414
414 #Full multivariate model
415
416 #specify some starting values for a 7x 7 among-individual matrix
417
418 init_values<-c(0.1,
419     0.01, 0.1,
420     0.01, 0.01, 0.1,
421     0.01, 0.01, 0.01, 0.1,
422     0.01, 0.01, 0.01, 0.01,0.1,
423     0.01, 0.01, 0.01, 0.01, 0.01, 0.1,
424     0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.1,
425     0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.1,
426     0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.1 )
427
428
429 multivar<-asreml(cbind(Time_app_AS, Time_app_BS, LatencyAS, LatencyBS, relAreaS) ~ trait +
430
431     at(trait,1):Trial + at(trait,1):Order_caught + at(trait,1):Maze_position +
432     at(trait,2):Trial + at(trait,2):Order_caught + at(trait,2):Maze_position +
433     at(trait,3):Trial + at(trait,3):Order_caught +
434     at(trait,3):Maze_position +
435     at(trait,4):Trial + at(trait,4):Order_caught +
436     at(trait,4):Maze_position +
437     at(trait,5):Trial,
438     random = ~str(~trait:ID + at(trait,1):ID:Trial + at(trait,2):ID:Trial
439         +at(trait,3):ID:Trial + at(trait,4):ID:Trial,
440     ~us(9, init =init_values):id(63)),
441     residual =~ units:indh(trait), #need to constrain final Vr somehow
442     data=df_maze,
443     na.action = na.method(x="include", y="include"))
444
445 #Extract results, check convergence and summarise main results
446 multivar$converge
447 summary(multivar)
448
449 ###correlation instead of variance structure
450

```

```

451 #specify some starting values for a 5x 5 among-individual matrix
452 init_values_cor<-c(0.1,0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 1, 1, 1, 1, 1 )
453
454 tricor<-asreml(cbind(Time_app_AS, Time_app_BS,relAreaS) ~ trait +
455     at(trait,1):Trial + at(trait,1):Order_caught + at(trait,1):Maze_position +
456     at(trait,2):Trial + at(trait,2):Order_caught + at(trait,2):Maze_position +
457     at(trait,3):Trial,
458     random = ~str(~trait:ID + at(trait,1):ID:Trial + at(trait,2):ID:Trial,
459     ~corgh(5, init =init_values_cor):id(63)),
460     residual =~ units:indh(trait), #need to constrain final Vr somehow
461     data=df_maze,
462     na.action = na.method(x="include", y="include"))
463
464 #Extract results, check convergence and summarise main results
465 tricor$converge
466 summary(tricor)$varcomp
467
468
469 ##### compare full model vs model with correlations set to 0 #####
470
471 init_values_cor_null <- c(0,
472     0,0,
473     0.1,0,0,
474     0,0.1,0,0,
475     1,1,1,1,1)
476
477 names(init_values_cor_null) <- c("F",
478     "F","F",
479     "P","F","F",
480     "F","P","F", "F",
481     "P","P","P", "P","P")
482
483 tricor_null<-asreml(cbind(App_AS, App_BS,relAreaS) ~ trait +
484     at(trait,1):Trial + at(trait,1):Order_caught + at(trait,1):Maze_position +
485     at(trait,2):Trial + at(trait,2):Order_caught + at(trait,2):Maze_position +
486     at(trait,3):Trial,
487     random = ~str(~trait:ID + at(trait,1):ID:Trial + at(trait,2):ID:Trial,
488     ~corgh(5, init =init_values_cor_null):id(63)),
489     residual =~ units:indh(trait), #need to constrain final Vr somehow
490     data=df_maze,
491     na.action = na.method(x="include", y="include"))
492
493 tricor_null$converge
494 summary(tricor_null)$varcomp
495
496 pchisq(2*(tricor$loglik - tricor_null$loglik),
497     2, lower.tail = FALSE)
498
499
500

```