Application of the univariate model from

Molenaar, Dolan, van der Sluis, & Boomsma (in press) in BGA

Data

We analyze the Osborne data (Osborne, 1980), which include the scores of 328 Caucasian twin pairs on various tests of cognitive abilities. The 328 twin pairs included 171 MZ twins (84 males, 87 females), and 157 DZ twins, of which 133 were same sex twins (51 male-male, 82 female-female) and 24 were opposite sex twins. Mean age was 15.49 (sd: 1.56; min: 12; max: 20). We are aware that the sample size in this application is relatively small compared to the sample size used in the simulation study above. We use this data set nevertheless as it is useful as both a univariate application and a multivariate application (see the next section).

We consider the 13 'Basic Test Batteries' (see Osborne, 1980). These include the Calendar Test (CT), the Cube Comparison Test (CC), the Wide Range Vocabulary Test (WV), the Surface Development Test (SD), the Simple Arithmetic Test (AR), the Form Board Test (FB), the Self-Judging Vocabulary Test (SV), the Paper Folding Test (PF), the Object Aperture Test (OA), the Identical Pictures Test (IP), the Newcastle Spatial Test (NS), the Spelling Achievement Test (SA), and the Mazes Test (MT). For each twin member we calculated the score of the first principal component (PC1) of the scores on these 12 tests. The observed score variances, i.e., var(Y_1) and var(Y_2), were 0.92 and 0.88, respectively, in the DZ twins, and 0.83 and 0.76 in the MZ twins. The correlation among the scores was .68 for the DZ twins and .88 for the MZ twins. In addition, the observed scores distribution did not depart significantly from that of a normal distribution, as established by the Shapiro-Wilks test (all p-values were >.1; in addition, skewness coefficients were close to 0, kurtosis coefficients were close to 3 as expected under a normal distribution for the observed data).

Results

We investigated the presence of AxE, and/or AxC effects in these data. Table 1 provides an overview of the modeling results. To assess the goodness of fit of the models, we considered the Akaike Information Criterion (AIC) and the likelihood ratio tests (LRT).

In the case of the ACE-model, we started by fitting the ACE-AxE-AxC model to the data. Next, we dropped the AxC effect from the model (resulting in an ACE-AxE model). The LRT showed that the fit of this more parsimonious model was not significantly worse [$\chi^2(1) = 1.60$, $p = .21$]. Dropping the AxE interaction from the ACE-AxE-AxC model (i.e., fitting an ACE-AxC model) resulted in a significant deterioration of the model fit as indicated by the LRT [$\chi^2(1) = 6.66$, $p<.001$]. In addition to the LRT, the AIC also indicated worse model fit compared to the ACE-AxE model.

In Table 2, the model implied conditional variances and marginal variances are shown for factor A, C, and E, and for the total variance, i.e., the variance of Y_j. As can be seen, the variance of Y_j predicted by the ACE-AxE-AxC model (0.87) is close to the observed variance (as reported above).

Conclusion

Notwithstanding the small sample size, we detected an AxE interaction in the PC1 scores of the Osborne data. AxC, in contrast, appeared to be absent. It is not surprising that we detected this AxE interaction in a relatively small sample, as the effect size appeared to be quite large as compared to the effect sizes we considered in our simulation. From the parameter estimates we can conclude that the variance of E is increasing across A (i.e., $\beta_1 = 0.59$, see Table 1), indicating that in the PC1 scores, the unique environmental effects cause more variance for higher levels of A. That is, for increasing genetic levels, differences between twins in phenotypes are larger because differences in environments increase. As pointed out by Molenaar, van der Sluis, Boomsma & Dolan (2011), this is consistent with the notion of ability differentiation in which the general intelligence factor is hypothesized to be a weaker source of individual differences at higher levels of this factor (Deary, et al. 1996).

Table 1.

Parameter estimates (95% confidence intervals) and fit statistics for the different models in the univariate illustration.

Model	**Parameter estimates**					**Fit statistics**	
	σ_A^2	σ_E^2		σ_C^2			
		β_0	β_1	γ_0	γ_1	*LRT*	*AIC*
ACE-AxE-AxC	0.38	-2.72	0.63	-0.89	-0.13	-	98.06
	(0.24;0.51)	(-3.10; -2.38)	(0.20; 1.05)	(-1.43; -0.55)	(-0.34; 0.08)		
ACE-AxE	0.40	-2.70	0.59	-0.93	-	1.60	97.66
	(0.25; 0.51)	(-3.07; -2.35)	(0.12; 1.01)	(-1.53; -0.56)			
ACE-AxC	0.37	-2.43	-	-0.92	-0.03	6.66	104.72
	(0.25; 0.55)	(-2.66; -2.18)		(-1.49; -0.56)	(-0.29; 0.18)		
ACE	0.37	-2.43	-	-0.92	-	6.78	100.84
	(0.25; 0.55)	(-2.65; -2.18)		(-1.49; -0.56)			

Note. For the fit statistics, best values are underlined for each class of model. LRT is a likelihood ratio test between the corresponding model and the full model, ACE-AxE-AxC with df = 1.

Table 2.

Implied marginal and conditional variances of the A, C, and E factor, and the observed score variance for the different models in the univariate illustration.

Model	**Variable**	**Marginal variance**	**Conditional variance**						
ACE			*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*
	A	0.38							
	C	0.41	0.61	0.53	0.47	0.41	0.36	0.32	0.28
	E	0.08	0.01	0.02	0.04	0.07	0.12	0.23	0.44
	y	0.87	0.62	0.55	0.50	0.48	0.48	0.55	0.71