

# Genetic and Environmental Influences on Developmental Continuity and Change in Activity Level in Toddlers

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## Abstract

The present study used mechanical motion recorders (actigraphs) to explore genetic influences on developmental change in activity level (AL) in a sample of over 300 twin pairs assessed at 2 and 3 years of age. At both ages, twins wore actigraphs for a 48-hour period in the home and in laboratory test and play episodes. Longitudinal model-fitting analyses revealed that AL was genetically influenced at all ages and in all situations. Moreover, there was little evidence of differential heritability across age. The genetic factors that influence AL in the home covaried perfectly across age; however, this was not the case for AL in the lab. For both the lab play and situations, significant new genetic variance emerged at age 3. Thus genes contribute to the stability of AL in the home, and to both stability and change in AL in the lab.

## Introduction

- Activity level (AL) is a pivotal temperament dimension in infancy and early childhood, but little is known about the role that genetic factors play in the development of AL.
- The few longitudinal studies exploring genetic and environmental influences on continuity and change in AL have relied on parent or observer ratings which yield equivocal conclusions about developmental change.
- Differential Heritability Across Age**
- Early studies of AL suggest that the heritability of AL may increase with age (Braungart et al., 1992; Cyphers et al., 1990; Matheny, 1983, 1989; Riese, 1990; Stevenson & Fielding, 1985), but these studies relied on parent and observer ratings of AL.
- The reliabilities of rating measures tends to increase with age which may account for age-related increases in heritability.
- Similarly, differential validity across age may be a problem. Parent ratings of AL are prone to contrast effects—rater biases that magnify behavioral differences between twins and result in overestimates of heritability. Parent rating studies that suggest increases in heritability also tend to show increasing contrast effects.

### Genetic Influences on Continuity and Change

- There is also research that suggests genetic influences on developmental change in AL. In the MacArthur Longitudinal Twin Study, AL was assessed by observer ratings at 14, 20, 24 and 36 months of age. New genetic effects emerged at 36 months, but genetic change coincided with changes in the content of the behavioral rating scale (Saudino & Cherry, 2001). Consequently, it is difficult to distinguish between changes due to development and changes due to measurement.

### This Study

- Although there are hints of increased heritability and new genetic effects, these effects may be artifacts of age-related differences in the psychometric properties and/or in the content of the instruments used to assess AL. Developmental change is confounded with changes in the properties of the measures used and consequently, little can be said about the etiology of continuity and change in AL.
- The present study addresses these problems by using mechanical motion recorders (actigraphs) to assess AL.

## Methods

### Sample

- 144 monozygotic (MZ) and 168 dizygotic (DZ) twin pairs assessed within approximately 2 weeks of their 2<sup>nd</sup> and 3<sup>rd</sup> birthdays.

### Procedure

- At each age, the procedure involved 2 visits, 48-hours apart, to the laboratory.
- At the initial visit:
  - Actigraphs were attached.
  - One twin was assessed in a standardized test situation, while the other twin was assessed within a laboratory play situation (see below).
- At the second visit:
  - Test/play situations were reversed for each twin.
  - Actigraphs were removed.

- Mechanical Measure of AL.** Twins wore Minimeter Actical actigraphs (Figure 1) on all four limbs for 48 hours. Actigraphs collect data in real time allowing us to examine AL during specific time segments (e.g., home, test and play situations).
- Lab Test Situation.** The Mental Scale of the *Bayley Scales of Infant Development—Second Edition (BSID-II)* (Bayley, 1993) provided a structured test situation for assessing AL (Figure 2).
- Lab Play Situation.** The AL episodes, *arc of toys*, *figdget video*, *workbench*, and *corral of balls*, from the *Laboratory Temperament Assessment Battery - Preschool Version (Lab-TAB; Goldsmith, Reilly, Lemery, Longley & Prescott, 1995)* provided standard play situations for assessing AL (Figures 3 to 6).

### Longitudinal Behavior Genetic Model-Fitting

- Separate bivariate Cholesky models were fit to the AL data for each situation. The model, depicted as a path diagram in Figure 7, decomposes the phenotypic variance at 2 and 3 years into genetic (additive) and environmental variance that is common to both ages and unique to 3 years.
- The phenotypic variances at 2 and 3 years are represented by the rectangles. The circles represent latent genetic and environmental variables. A1, C1, and E1, are the common genetic factor, the common shared environmental factor, and the common nonshared environmental factor, respectively, that is shared at both ages. A2, C2, and E2 are factors that are unique to 3 years of age.
- Genetic **continuity** is suggested when path coefficients leading from the common A factor are significant. A significant A2 path would indicate genetic independence of the heritability of the trait at each age.
- Using this model we can estimate heritability, and shared and nonshared environmental variance; genetic and environmental contributions to phenotypic continuity, and age-to-age genetic correlations indicating the extent to which genetic effects at one age correlate with genetic effects at another, independent of the heritability of the trait at each age.



Figure 1. Actical and Actical Attachment



Figure 2. Lab Test: Bayley



Figure 3. Lab Play: Arc of Toys



Figure 4. Lab Play: Figdget Video



Figure 5. Lab Play: Workbench



Figure 6. Lab Play: Corral of Balls

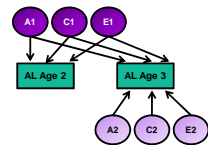


Figure 7. Cholesky Model

## Results

### Phenotypic Stability

- Stability of AL was .32 in the play situation, .40 in the test situation and .43 in the home, indicating both continuity and change in the rank ordering of AL across early childhood.

### Twin Intra-class and Cross Correlations (Table 1)

- At both ages and in all 3 situations MZ intraclass correlations exceed DZ correlations suggesting that AL is genetically influenced.
- For AL in the home DZ intraclass correlations exceed one-half the MZ correlation suggesting that shared environmental effects also influence AL in this situation.
- MZ twin cross correlations (i.e., the correlation between Twin 1's score for AL at age 2 with Twin 2's score for AL at age 3 and vice versa) exceeded DZ twin cross correlations suggesting that covariance across age is genetically influenced.

Table 1. Twin Intra-class and Cross Correlations

	Age 2		Age 3		Cross Correlations	
	MZ	DZ	MZ	DZ	MZ	DZ
Home	.87	.70	.81	.67	.49	.23
Test	.53	.32	.56	.36	.38	.26
Play	.48	.26	.44	.24	.26	.17

Note. All correlations significant at  $p < .05$

### Model-fitting Results

- Table 2 presents the parameter estimates from the best-fitting longitudinal genetic models.
- As suggested by the pattern of correlations, AL was genetically influenced at all ages and in all situations. Shared environmental influences also contributed significantly to AL in the home.
- There is no evidence of changes in the magnitude of genetic or environmental variances across age.
- The fact that the magnitudes of heritabilities are similar across age does not mean that the same genetic effects are operating at 2 and 3 years. Genetic correlations indicating the extent to which genetic effects at age 2 overlap with those at age 3 show that the genetic factors that influence AL in the home at ages 2 and 3 covary perfectly (i.e., no genetic change), but this is not the case for AL in the lab.
- In fact, for both the lab play and test situations significant new genetic variance emerged at age 4. Approximately 65% of the genetic variance on AL in the play situation, and 48% of AL in the test situation was unique to age 3.

Table 2. Genetic and Environmental Sources of Variance and Covariance Across Age

	Age 2			Age 3			Covariances		
	$a^2$	$c^2$	$e^2$	$a^2$	$c^2$	$e^2$	$r_G$	$r_C$	$r_E$
Home	.31 (.18-.46)	.56 (.40-.68)	.13 (.10-.17)	.25 (.12-.42)	.55 (.38-.67)	.20 (.16-.25)	1.0 (.68-1.0)	.28 (.03-.46)	-.05 (-.18-.10)
Play	.49 (.38-.59)	—	.51 (.41-.62)	.48 (.36-.58)	—	.52 (.42-.63)	.57 (.39-.76)	—	.03 (-.11-.16)
Test	.55 (.45-.64)	—	.45 (.36-.55)	.54 (.45-.63)	—	.46 (.37-.55)	.72 (.58-.86)	—	.02 (-.16-.12)

Note.  $a^2$ =genetic variance,  $c^2$ =shared environmental variance,  $e^2$ =nonshared environmental variance,  $r_G$ =genetic correlation,  $r_C$ =shared environmental correlation,  $r_E$ =nonshared environmental correlation.

## Conclusions

- When assessed via actigraphs, there is no evidence of differential heritability across age. This suggests that prior findings hinting at differential heritability may be a result of the psychometric properties of the measures used to assess AL.
- In all situations, genetic influences contributed to **continuity** in AL across age. For AL in the home, shared environmental factors also contributed to stability across age, but to a lesser extent.
- Change** in AL in the **home** is due to shared and nonshared environmental factors. The finding of new nonshared environmental effects across age is consistent with prior research but novel shared environmental effects at age 3 are particularly interesting as they reflect changes in family-wide experiences perhaps indexing age-related changes in how parents structure their children's environments.
- Change** in AL in **both lab situations** is due to both genetic and nonshared environmental factors.
- The findings of new genetic effects in the lab at age 3 are consistent with earlier results from the MacArthur Longitudinal twin study (MALT5) which also found novel genetic variance on observed AL at age 3 (Saudino & Cherry, 2001). However, in MALT5 genetic change coincided with changes in the AL measure, raising the question as to whether genetic change simply reflects differences in the measurement of AL.
- Our use of actigraphs to assess AL across age suggests that prior findings of novel genetic effects are real (but only in the lab situations) and allows for more interesting hypotheses about the source of this new genetic variance. One possibility is that the new genetic effects in the lab situations may reflect increased self-control/self-regulation or adaptability to novel social situations.
- The different sources of continuity and change for AL in the home and lab situations highlights the need to consider situations when evaluating AL (and likely other temperamental dimensions). Indeed, in previous work with this sample we have found that, to some extent, different genetic effects operate on AL in the home and the lab (Saudino & Zapfe, 2008).
- Similarly, the finding of novel sources of variance at age 3 reminds us that the factors that influence individual differences in AL change across age and that genes can be the source of change as well as continuity.
- Age and situations should be carefully considered in molecular genetic work that seeks to identify specific genes associated with AL.

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