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REPORT

A longitudinal behavioral genetic analysis of task persistence

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Abstract

Change in task persistence was assessed in two annual assessments using teachers', testers', and observers' ratings. Participants included 79 monozygotic and 116 same-sex dizygotic twin pairs who were in Kindergarten or 1st grade (4.3 to 7.9 years old) at the initial assessment. Task persistence was widely distributed and higher among older children and girls. Overall, there was modest growth in persistence over time, and moderate stability of individual differences. Most of the stability was accounted for by genetic influences, whereas most of the change was accounted for by nonshared environment, including an association with observed differential maternal warm supportive behavior.

Introduction

Persistence with challenging tasks is one of several commonly used indicators of attention regulation, and is associated with a variety of behaviors spanning cognitive performance and behavioral adjustment (Barkley, 1997; Jennings & Dietz, 2003; Posner & Rothbart, 2005). Individual differences in attention span and task persistence arise from genetic and non-genetic influences, with candidate genes in the dopamine neurotransmitter system implicated along with environmental factors such as maternal warmth (Gagne, Saudino & Cherny, 2003; Goldsmith, Buss & Lemery, 1997; Schmitz, 2003; Maher, Marazita, Ferrell & Vanyukov, 2002; Petrill & Deater-Deckard, 2004).

Though the literature just described includes ample evidence of stability in individual differences in attention span and persistence over time, the mechanisms that underlie stability and change in individual differences in persistence have not been elucidated. In the first wave of the current longitudinal twin study, we developed a multi-informant and method task persistence construct that included teachers', testers', and observers' ratings (Deater-Deckard, Petrill, Thompson & DeThorne, 2005), a construct that was developed from a previous study of preschool children (Petrill & Deater-Deckard, 2004). Cross-sectional analyses revealed a shift in genetic and non-genetic variance from 4 to 8 years. There was negligible heritability and substantial shared (i.e. sibling similarity) and nonshared (i.e. sibling differentiation) environment estimates for younger children, but substantial heritability and nonshared environment and negligible shared environment for older children. Though descriptively useful, the prior cross-sectional analysis did not permit a test of how genetic and environmental influences account for stability and change in individual differences in the same individuals over time – the goal of the current two-wave longitudinal study.

Our aim was to estimate genetic, shared environment and nonshared environment correlations underlying stability in task persistence over one year, while also examining influences on instability or change. If the genetic correlation between the two assessments was found to be substantial, this would suggest that the longitudinal stability in task persistence was influenced by a common set of genetic factors. Similarly, if the shared or nonshared environment correlation was significant, this would implicate non-genetic influences on task

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persistence that maintain sibling similarity or sibling differentiation in task persistence over time. Such testing for genetic and environmental influences on stability and change is informative, because it clarifies the etiology of individual differentiation.

Knowing whether and how the genetic, shared environmental and nonshared environmental influences on task persistence contribute to stability and change yields more precise predictions about how specific genes and environments operate in development. There is no question that the field needs to begin moving beyond estimates of variance derived from behavioral genetic analyses, to tests of the effects of these specific genetic and environmental factors. Though we were not able to examine candidate genes in the current study, we were able to consider candidate environment effects. There is a literature showing that better self-regulation (including attention), cognitive performance, and achievement are associated with warm supportive parenting (i.e. scaffolding, including exposing child to stimulating materials, age-appropriate guided participation in learning, and warm acceptance of child; Bradley, Corwyn, Burchinal, Pipes-McAdoo & Garcia-Coll, 2001; Rogoff, 2003; Gauvain, 2001). Our previous study of 3-year-olds showed that some of this effect operates through shared environmental mechanisms, though the presence of nonshared environmental mechanisms on stability or change was not ruled out (Petrill & Deater-Deckard, 2004). In the current study, we examined maternal behaviors during observations of structured, task-based dyadic mother–child interactions in the home. To the extent that shared or nonshared environmental influences emerged in the longitudinal analyses of stability and change in task persistence, we examined maternal warm supportive behavior to see if it accounted for those statistical effects.

Method

Participants

The longitudinal data are from the first wave and second wave (one year later) of the Western Reserve Reading Project that includes 79 monozygotic (MZ, 63% female) twin pairs and 116 dizygotic (DZ, 52% female) same-sex twin pairs (wave one age, $M = 6.12$ yrs, SD = 0.69 yrs, range = 4.32–7.92 yrs). Parental education varied across families but was similar for fathers and mothers on average: 12–17% high school or less, 23–29% some college or associates degree, 30–31% bachelor's degree, 4–6% some post-graduate education, and 5% post-graduate degree. The majority was Caucasian (92%) and lived in two-parent households (6% single mothers).

Procedures

During two home visits that were one year apart, we measured task persistence using teachers' reports of child behavior at school, and testers' and observers' reports of child behavior in the home. The twins and parents completed a battery of behavioral and cognitive assessments. This included videotaped mother–child interactions (16 minutes) in which the pair completed two mildly frustrating games requiring good attention, persistence, and cooperation – drawing pictures using an Etch-A-Sketch drawing toy, and moving a marble through a tilting maze box. For each game, mother and child were assigned one of two dials that operated the toy, and were asked not to touch each other's dials. Testers completed brief questionnaires once the home visit was completed, and parents completed questionnaires before or shortly after the home visit. Teachers completed questionnaires through the mail.

Measures

Task persistence

Task persistence was measured as a composite based on teachers', testers', and observers' reports. Teachers' ratings were gathered using the Teacher Report Form or TRF (Achenbach, 1991) that includes a series of 3-point Likert scale items (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true). We selected three items that assess task persistence most directly (4: *fails to finish things*; 8: *cannot concentrate or pay attention for long*; 78: *inattentive, easily distracted*).

Testers completed Bayley's (1969) Behavior Record. We used the two items relevant to task oriented behavior (*on task behavior*: 1 = constantly off task, does not attend, 3 = off task half the time, 5 = constantly attends; *persistence*: 1 = consistently lacks persistence, 3 = lacks persistence half the time, 5 = consistently persistent). Two different testers rated each twin within a pair.

Observers (different individuals from those who completed testers' ratings) coded the videotaped parent–child interaction using the Parent–Child Interaction System of global ratings (PARCHISY; see Deater-Deckard *et al.*, 2005). Two different observers rated each twin within a pair. Coders achieved Cronbach's $\alpha > .75$ during training and maintained reliability throughout data collection. We used the PARCHISY item regarding *on-task behavior* (1 = no interest in task; no initiative; does not begin task; 3 = begins task but does not attempt to complete task; 5 = completes task with only a few instances of off-task behavior; 7 = constant interest and persistence, always on-task).

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Table 1 *Task persistence first principal component: explained variance, alpha coefficient, and factor loadings*

	Wave 1	Wave 2
Item variance explained	46%	46%
Item internal consistency (α)	.75	.73
Item factor loadings:		
Teacher rating 'cannot pay attention'[a]	.79	.87
Teacher rating 'inattentive, distracted'	.78	.82
Teacher rating 'fails to finish things'	.72	.72
Tester rating 'on task'	.69	.68
Tester rating 'persistent'	.60	.54
Observer rating 'on task'	.42	.29

Note: [a] Higher scores indicate less task persistence; reverse-scored for analyses.

In the first wave data, we derived a composite task persistence score with good internal consistency and predictive validity that comprised the three teacher-rated items, two tester-rated items, and one observer-rated item. We found a very similar structure to the data in wave two, as shown in the comparison of the first principal component in each wave in Table 1. Note that the observer-rated item showed a loading of < .4 in wave two. We examined the wave two composite with and without the observer-rated item, and the subsequent results did not differ. Also, the inclusion of a third informant and method (observer rating of videotaped tasks) likely increases predictive validity compared to having only two sources (teacher and tester; e.g. Horowitz, Inouye & Siegelman, 1979). Therefore, we retained all six items in the composite scores. The items were standardized, averaged, and standardized again to yield task persistence *z*-scores, separately at each wave.

Maternal warm supportive behavior

Observers also used the videotaped interactions to code the degree to which mothers showed warm supportive behavior in their interactions with each twin. Observers completed two correlated items ($r = .30$) from the PARCHISY that were averaged to derive the maternal warm supportive behavior score. These included *positive affect* including laughter and smiling (1 = no positive affect shown; 3 = a few instances of positive affect; 5 = positive affect for more than half of interaction; 7 = positive affect throughout interaction) and *positive control* including use of praise, explanation, and questions to elicit elaborated speech (1 = no positive control shown; 3 = a few instances of positive control, with reliance on explicit directions, e.g. 'up', 'down', 'over'; 5 = two or more instances of positive control, with some explicit directions; 7 = exclusive use of praise, explanation, and questioning). This observer-rated score was correlated .40 with testers' global rating of maternal warmth following the home visit, though only the PARCHISY score was used because the tester rating does not yield separate scores for each twin.

Results

Task persistence at both waves varied widely between children, as can be seen in the distributions of the original scales that together define the composite scores (see Table 2). At both waves, the full range or nearly the entire range of possible scores was represented. Examination of the distribution of the composite *z*-scores showed that persistence was widely distributed, but with negative skew (wave one = –1.500, wave two = 1.62) and kurtosis (wave one = 2.13, wave two = 2.56). Higher persistence was associated modestly with being older [wave one, $r\ (384) = .14$, $p < .01$; wave two, $r\ (384) = .13$, $p < .01$] and being female [sex coded as 1 = male, 2 = female; wave one, $r\ (386) = -.10$, $p < .05$; wave two, $r\ (386) = -.20$, $p < .001$]. There were no differences by zygosity. Also, there was little evidence of mean level change in persistence from wave one to wave two, as can be seen in the comparison of the individual scales in Table 2.

Overall sibling similarity in task persistence was moderate at both assessments: wave one intra-class $r\ (194) = .49$, $p < .001$; wave two intra-class $r\ (194) = .44$, $p < .001$. Because we did not have the statistical power to examine age and sex effects within a behavioral genetic framework, we computed standardized residual scores after removing the variance in task persistence attributable to age and sex. These residuals were used in all of the subsequent analyses, though we conducted analyses in which age and sex were not controlled and the results were very similar to those reported below.

Individual differences in persistence were moderately stable over time, $r\ (389) = .46$, $p < .001$ (see Table 3). This stability coefficient was exactly the same when we estimated it based on only one twin per family (to control for non-independence of twin data). We computed twin

Table 2 *Descriptive statistics for indicators comprising the task persistence composite score (*N *= 390 children in 195 twin pairs)*

	Wave 1			Wave 2		
Item (possible range)	*M*	SD	range	*M*	SD	range
Teacher rating (0 to 2)[a]	0.28	.47	0.0 to 2.0	0.26	.46	0.0 to 2.0
Tester rating (1 to 5)	4.28	.75	1.5 to 5.0	4.54	.58	2.0 to 5.0
Observer rating (1 to 7)	6.52	.69	3.0 to 7.0	6.71	.55	3.0 to 7.0

Note: [a] Higher scores indicate less task persistence; reverse-scored for analyses.

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Table 3 *Task persistence: sibling intra-class correlations and variance/covariance matrices for monozygotic (MZ,* n *= 79 pairs) and dizygotic twins (DZ,* n *= 116 pairs)*

	Intra-class correlation matrix				Variance/covariance matrix			
	1.	2.	3.	4.	1.	2.	3.	4.
MZ twins								
1. Twin 1, Wave 1	1				.75			
2. Twin 1, Wave 2	.72	1			.37	.70		
3. Twin 2, Wave 1	.49	.48	1		.59	.40	.88	
4. Twin 2, Wave 2	.48	.49	.44	1	.31	.34	.41	.74
DZ twins								
1. Twin 1, Wave 1	1				1.04			
2. Twin 1, Wave 2	.31	1			.49	1.07		
3. Twin 2, Wave 1	.45	.26	1		.28	.18	.74	
4. Twin 2, Wave 2	.26	.45	.37	1	.33	.40	.38	1.04

Note: all correlations significant at $p < .05$, two-tailed.

intra-class correlations for task persistence at both waves by zygosity (also in Table 3), and there was clear evidence of twin similarity. To test whether there were common or independent genetic, shared environmental, and nonshared environmental effects in the variance in task persistence within each wave as well as effects in covariance over time, a bivariate Cholesky decomposition was used to partition the variances of and covariances between task persistence at wave one and task persistence at wave two (Neale & Cardon, 1992; see Figure 1). In this model, latent variables are estimated that represent independent and overlapping additive genetic effects (A), additive shared environment effects (C), and additive nonshared environment effects including error (E), as well as residual genetic (a), shared environmental (c), and nonshared environmental (e) variance. The pathways between latent variables representing genetic variance or covariance across twins are set at 1 for monozygotic (MZ, identical) twins and .5 for dizygotic (DZ, fraternal) twins. The pathways for shared environmental variance or covariance across twins are set at 1 for MZ and DZ twins, whereas the pathways for nonshared environmental variance or covariance across twins are set at 0 for MZ and DZ twins.

The model's statistical fit to the data was acceptable, $\chi^2(11) = 16.69$, $p = .117$, $AIC = -5.313$, $RMSEA = 0.074$, and it yielded univariate genetic parameters as shown in the left side of Table 4. The univariate genetic and nonshared environmental variance estimates generally were moderate and statistically significant in both waves, whereas shared environmental variance was not significant.

The paths in the bivariate model also were used to estimate bivariate genetic parameters that correspond to overlapping genetic and non-genetic variance (i.e. genetic correlation, shared environmental correlation, and nonshared environmental correlation) underlying the phenotypic correlation between task persistence at the

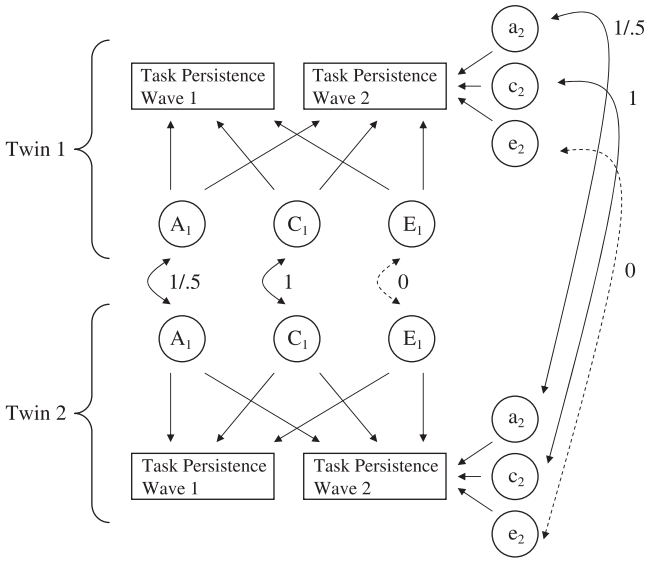


Figure 1 *A bivariate Cholesky decomposition was used to partition the variances of, and covariances between, Task Persistence at Wave One and Task Persistence at Wave Two, into genetic and non-genetic components. Latent variables represent overlapping additive genetic effects (A), additive shared environment effects (C), and additive nonshared environment effects including error (E), as well as residual genetic (a), shared environmental (c), and nonshared environmental (e) variance. In this model, the pathways between latent variables representing genetic variance or covariance across twins are set at 1 for monozygotic (MZ, identical) twins and .5 for dizygotic (DZ, fraternal) twins. The pathways for shared environmental variance or covariance across twins are set at 1 for MZ and DZ twins, whereas the pathways for nonshared environmental variance or covariance across twins are set at 0 for MZ and DZ twins.*

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Table 4 *Model variance estimates (95% confidence intervals) and correlations*

	Genetic variance		Genetic correlation	
Wave 1	.69	(.39–.78)	1.00	
Wave 2	.33	(.04–.66)	.81*	1.00
	Shared env. variance		Shared env. correlation	
Wave 1	.03	(.00–.20)	1.00	
Wave 2	.19	(.00–.43)	1.00	1.00
	Nonshared env. variance		Nonshared env. correlation	
Wave 1	.28	(.18–.34)	1.00	
Wave 2	.48	(.32–.60)	.04	1.00

Note: * two-tailed $p < .05$.

Table 5 *Bivariate Pearson correlations between monozygotic twin relative difference in task persistence change and twin relative difference in maternal warm supportive behavior (n = 76 pairs)*

	Difference in task persistence change
Differential maternal behavior:	
Wave 1	.24*
Wave 2	.18
Wave 1/Wave 2 average	.28*

Note: * $p < .05$, two-tailed.

first and second waves. These are shown in the right side of Table 4. The path coefficient representing genetic covariance across the two waves was statistically significant and yielded a genetic correlation of .81. This corresponded with a significant bivariate heritability of .39. In contrast, neither the shared environment covariance path coefficient nor the nonshared environment covariance path estimate was significant, suggesting that nearly all of the stability of individual differences in task persistence was accounted for by overlapping genetic influences across the two waves.

Next, we considered the bivariate results with respect to the residual genetic and non-genetic variance in the wave two scores (controlling for wave one scores). At wave two, neither the residual genetic path estimate (.33, *95% CI* = .00–.62) nor the residual shared environment path coefficient (.00, 95% *CI* = .00–.52) was significant. However, there was a significant residual nonshared environment path coefficient (.67, *95% CI* = .57–.77), suggesting that nonshared environmental influences accounted for most of the instability in task persistence.

To examine this nonshared environmental variance on change in task persistence, we examined identical twin differences. This is the most direct way to identify potential nonshared environment influences because monozygotic twins have the same genotypes; only nonshared environment can account for identical twin differences, although it is important to emphasize that this includes any systematic error variance. We computed change scores by subtracting the wave one task persistence composite *z*-score from the wave two task persistence composite *z*-score. We then computed an identical twin difference score of those change scores (twin one change score – twin two change score). To estimate relative differences in maternal behavior, we computed a relative twin difference in maternal behavior scores separately in each wave – bearing in mind that maternal behavior was only moderately stable over time; twin one r (163) = .39, $p < .001$; twin two r (169) = .34, $p < .001$. We also averaged the wave one and wave two differential maternal behavior scores, r (161) = .18, $p < .05$, to derive a single differential maternal behavior score that was a composite based on her differential warmth at both assessments. The estimated bivariate correlations between the task persistence change difference score and the maternal behavior difference scores are shown in Table 5, and suggest a statistically significant albeit modest association.

Discussion

The current longitudinal behavioral genetic study extended recent research on the development of task persistence through an exploration of the genetic and non-genetic sources of stability and instability over a one-year period. There were two main findings. First, individual differences in task persistence were stable over one year, and this stability was accounted for predominantly by stable genetic influences. Second, there also was instability over this one-year period, the bulk of which was accounted for by nonshared environment effects.

With respect to the first finding, the magnitude of the one-year stability coefficient (close to .5) is noteworthy given that the task persistence scores included ratings from independent sources within each wave and typically across the two waves (i.e. different teachers and observers). The advantage to using a multi-informant and method composite score is that it constrains the analysis by forcing the examination of the variance in behavior that is common or overlapping across different settings and informants' reports. In this way, a multimethod and informant composite score, though typically less internally consistent than a mono-method score, has better predictive validity and is more likely to yield results that will be replicated (Rushton, Brainerd & Pressley, 1983).

The behavioral genetic analyses showed that genetic influences on task persistence that differentiated children from one another in the first wave continued to do so in the same way over time. This leads to the prediction that

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in subsequent research, candidate gene effects will be associated not only with individual differences at one time, but will account for most of the stability over time. There are some promising leads regarding candidate dopamine genes for various aspects of attention regulation (Maher *et al.*, 2002), but it will be years before the field has a well-replicated set of candidate genes available for testing this prediction. Though novel in its focus on observed task persistence, the current study's finding of a substantial genetic correlation for stability is much like the results from previous longitudinal behavioral genetic studies of a variety of cognitive phenotypes (for an overview see Petrill, Lipton, Hewitt, Plomin, Cherny, Corley & DeFries, 2004). When it comes to explanations for the stability of individual differences over time, genetic variation appears to be very important.

Turning to the second major finding, there was substantial residual nonshared environmental variance in task persistence after genetic and non-genetic effects on stability were controlled statistically. Thus, environmental influences that account for sibling differences (including measurement error) were largely responsible for the instability of task persistence scores over time. To identify potential systematic nonshared environment effects, and following on prior phenotypic and behavioral genetic research, we tested whether maternal differential warm supportive behavior with identical twins might account statistically for some of this nonshared environment effect on change – any differences between identical twins cannot be attributed to differences in genes. We found that within each twin pair, the child who was receiving warmer, more supportive and constructive guidance from her mother during dyadic cooperation tasks was more likely to show more growth or less declination in persistence over time, compared to her genetically identical co-twin.

Thus, within each family, the child with whom the mother was more warm and engaging was more likely to show improvements in task persistence over one year. We were able to identify this nonshared environmental link between maternal and child behavior even though shared method variance was minimized, and we were examining change scores. This suggests that the effect is quite robust, although there could be systematic error variance across the task persistence and maternal behavior scores that might contribute to some portion of the correlation between differential parenting and differential task persistence. Also, identifying a nonshared environmental process does not allow us to infer a causal direction of influence, given that these data are correlational. This effect could represent an influence of twin differences in persistence on greater differential maternal warmth (a child effect), an influence of differential parenting on subsequent twin differences in persistence (a parent effect), or a bi-directional process (see Turkheimer & Waldron, 2000).

The current results converge well with other recent evidence suggesting that sibling similarity in task persistence remains fairly stable over time, but that the causes of that stability shift with development – from shared environmental influences in early childhood to genetic influences in middle childhood (Deater-Deckard *et al.*, 2005). Although causality cannot be inferred from quasi-experimental behavioral genetic designs, the results also indicate that identifiable aspects of children's home environments – in this case, maternal warm supportive behaviors – play a role in the etiology of behavioral task persistence, the effects of which may shift with development from shared (causing sibling similarity) to nonshared (causing sibling differentiation) influences.

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