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A cross-sectional behavioral genetic analysis of task persistence in the transition to middle childhood

Kirby Deater-Deckard[1], **Stephen A. Petrill**[2], **Lee A. Thompson**[3], and **Laura S. DeThorne**[4]

1 *Department of Psychology, University of Oregon, USA*

2 *Center for Developmental and Health Genetics and Department of Biobehavioral Health, Pennsylvania State University, USA*

3 *Department of Psychology, Case Western Reserve University, USA*

4 *Department of Communication Disorders, Pennsylvania State University, USA*

Abstract

Task persistence, measured by a composite score of independent teacher, tester and observer reports, was examined using behavioral genetic analysis. Participants included 92 monozygotic and 137 same-sex dizygotic twin pairs in Kindergarten or 1st grade (4.3 to 7.9 years old). Task persistence was widely distributed, higher among older children, positively associated with standardized tests of cognitive performance and achievement, and negatively associated with parents', teachers' and observers' reports of behavioral problems. Cross-sectional analysis indicated a strong developmental shift from shared environment variance among younger children to additive genetic variance in older children.

Introduction

Beginning in early childhood, there are individual differences in persistence in task-based goal directed behavior. *Task persistence* is one aspect of self-regulated attention, cognition and behavior that is part of broader systems of executive function (e.g. goal directed and persistent behavior; Anderson, 2002) and temperament (e.g. effortful control; Rothbart, Ahadi & Evans, 2000). Task persistence is a key aspect of cognitive performance and academic motivation and achievement, and also is linked with fewer behavioral and self-regulation problems such as those indicative of attention deficit disorders (Barkley, 1997; Jennings & Dietz, 2003).

Molecular and behavioral genetic studies show evidence of genetic influences in task persistence, with indications of shared environmental variance (i.e. non-genetic influences leading to family member similarity) in preschool and early middle childhood being more mixed (Gagne, Saudino & Cherny, 2003; Petrill & Deater-Deckard, 2004; Schmitz, 2003; Schmitz, Saudino, Plomin, Fulker & DeFries, 1996). However, little is known about developmental change or stability of these effects, and the literature includes studies based on a variety of methods and informants which leads to inconsistencies in estimates. In the current study, we address these issues by investigating potential change in genetic and environmental influences using a cross-sectional design and a multi-informant composite measure.

Address for correspondence: Kirby Deater-Deckard, Department of Psychology, 1227 University of Oregon, Eugene, OR, USA; e-mail: kirbydd@uoregon.edu.

In a recent study of 3.5-year-old twins, Petrill and Deater-Deckard (2004) found that task persistence, measured as a composite of task-based performance as well as testers' and observers' ratings, included a moderate shared environmental effect and a modest heritable component. We extend this research by using a cross-sectional design (4 to 8 years old) and a more comprehensive multi-informant composite measure of task persistence. We focused on the preschool-to-school age transition because it is a time when (a) various aspects of cognitive and behavioral self-control are continuing to develop and (b) children are adapting to mounting expectations for on-task behavior in school while also acquiring more control over their own environments (e.g. Anderson, 2002; Eccles & Wigfield, 2002; Grolnick, Kurowski & Gurland, 1999).

From a developmental perspective, Scarr and McCartney (1983) proposed that shifts in the magnitude of gene–environment influences will occur in the transition from early to middle childhood as the effects of genes accumulate and as children increasingly select into and manage their own environments (i.e. evocative gene–environment correlation processes). They predicted shifts toward greater heritability (arising from increasing non-passive gene–environment correlation) and less shared environmental variance. There is evidence of this developmental shift in cross-sectional and longitudinal studies of cognitive performance (McCartney, Harris & Bernieri, 1990), but to our knowledge this theory has not been tested for task persistence. In light of Scarr and McCartney's theory and the literature on task persistence, we hypothesized that genetic variance would be greatest among older children and shared environmental variance greatest among younger children.

Method

Participants

The data are from the first wave of the Western Reserve Reading Project that includes 92 monozygotic (MZ, 63% female) twin pairs and 137 dizygotic (DZ, 52% female) same-sex twin pairs (age M = 6.12 yrs, SD = 0.69 yrs, range = 4.32–7.92 yrs) with complete data on task persistence. Parent education levels varied widely and were very similar for women and men: 1–2% high school or less, 39% some college, 30% bachelor's degree, 25% some postgraduate education or degree, 5% not specified. Most families were two-parent households (6% single mothers) and nearly all were Caucasian (92%).

Procedures

Task persistence was assessed using testers' and observers' ratings of child behavior in the home, and teachers' ratings of child behavior at school. During a three-hour home visit the twins and parents completed a battery of behavioral and cognitive assessments (see Petrill, Deater-Deckard, Thompson & DeThorne, 2004 for more information). In addition, the mother was videotaped while interacting with each twin separately for 16 minutes while they completed two mildly frustrating games requiring moment to moment cooperation and constant task persistence – drawing pictures using an Etch-A-Sketch drawing toy, and moving a marble through a tilting maze box. In both tasks, the mother and child each were assigned one of two dials that operates the toy, and were told not to touch each other's dials. Testers completed a brief questionnaire at the end of the home visit, and parents returned questionnaires to the testers that had been completed before the home visit. Teachers completed questionnaires through the mail.

Measures

Task persistence—Task persistence was assessed using reports from teachers, in-home testers and independent observers. A single composite score was derived across these methods and reporters, as described below in Results.

Teachers rated child behavior using the Teacher Report Form or TRF (Achenbach, 1991), which includes items rated on a 3-point Likert-type scale (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*); item 100, *fails to complete assigned tasks*, was not included because it was highly redundant with item 4. These items were reverse-scored (higher score = greater persistence). Tester ratings also were gathered. At the end of the home visit, testers completed items from Bayley's (1969) Behavior Record, which are rated on 5-point Likert-type scales. 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).

In regard to ratings by individual observers, a different research assistant coded the videotaped parent–child interaction after each home visit using the Parent–Child Interaction System of global ratings (Deater-Deckard, Pylas & Petrill, 1997). This involved viewing the videotaped interaction and completing a short questionnaire of items rated on 7-point Likert-type scales. A different assistant coded the tapes of each twin within a family to reduce rater bias effects. Coders achieved Cronbach's $\alpha > .75$ during training and maintained this level of reliability throughout data collection. For the current study, we used the 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).

Child cognitive performance, achievement and behavioral problems—Although the primary focus of the current study was on the task persistence measures, we also examined correlations with several other aspects of child cognitive and social-emotional development to examine the validity of the new task persistence composite. *Cognitive performance* was assessed using a short form of the Stanford-Binet Intelligence Scale that included Vocabulary, Comprehension, Bead Memory, Quantitative and Pattern Analysis (Thorndike, Hagen & Sattler, 1986). *Achievement* was assessed as the average of the four items (1 = far below grade level, 3 = at grade level, 5 = far above grade level; for reading, spelling, math and writing; $\alpha = .91$) from teachers' reports on the Teacher Report Form (Achenbach, 1991). *Externalizing behavior problems* (e.g. aggression, conduct problems) were reported by parents on the Child Behavior Checklist (Achenbach, 1991) and by teachers on the Teacher Report Form (Achenbach, 1991). Mothers' and fathers' ratings were correlated, r (252) = .52, $p < .001$, and were averaged for those who had both parents' reports (otherwise, only mother report was used). Parent and teacher agreement was modest, r (373) = .18, $p < .01$, so these were retained as separate scores. In addition, observers completed two items on the Parent–Child Interaction System of global ratings: (a) *expressed negative affect* (1 = none; 3 = several instances; 5 = more than half of interaction; 7 = constant) and (b) *non-compliance* with parents' or researchers' requests (1 = always done as asked; 3 = several instances; 5 = more than half of task, with a few instances of compliance; 7 = non-compliant throughout task, no instances of compliance). Negative affect and noncompliance were correlated, r (419) = .40, $p < .001$, so were standardized and averaged to yield a composite score. Observer, parent and teachers' ratings of child behavior problems were modestly correlated (parent-rated externalizing r (382) = .14, $p < .01$; teacher-rated externalizing r (352) = .21, $p < .001$), so the observer-rated score was retained separately.

Results

We began by testing the reliability of the task persistence composite. We used principal components factor analysis to evaluate the fit of a single factor to the items from three data sources (teachers, testers and observers). The factor accounted for 47% of the variance, and loadings ranged from .45 to .77 (see Table 1). We standardized and averaged each of the items to yield a composite score that was widely distributed. This variability could be seen in the individual items, with the entire range or nearly the entire range of possible scores represented –i.e. 2 to 7 on the observers' rating (a 1-to-7 scale), 1 to 5 on the testers' ratings (a 1-to-5 scale), and 0 to 2 on the teachers' ratings (a 0-to-2 scale). The composite's distribution showed moderate kurtosis and a negative skew but no ceiling. Task persistence was higher among children who were older, r (465) = .17, $p < .001$, and who had mothers with more years of education, r (440) = .17, $p < .001$. Task persistence did not differ by child sex, birth order or zygosity.

Though not the primary focus of this brief report, we estimated Pearson correlations with measures of cognitive skills, achievement and behavior problems as a check on the validity of the construct. We calculated the correlations for the entire sample of twins, and again separately for twin 1 (firstborn) and twin 2. As anticipated, greater persistence was associated with better cognitive performance/achievement and fewer behavioral problems, all significant at one-tailed $p < .001$; Stanford-Binet Sum of Area scores $r = .30$, teacher-rated scholastic performance $r = .37$, teacher-rated externalizing behavior problems $r = -.44$, parent-rated externalizing behavior problems $r = -.13$, observer-rated child non-compliant/negative affect $r = -.30$. The correlations were very similar across the sub-samples (twin 1's and twin 2's) compared to those estimated for the entire sample, and none of the twin 1/twin 2 correlations was significantly different. In addition, correlations were similar for boys and girls with the exception of the estimate for Stanford-Binet scores; girls r (256) = .39, $p < .001$, boys r (199) = .17, $p < .05$, Fisher r-to-z difference $p < .05$.

To estimate genetic and environmental parameters for the task persistence composite and to test whether these varied by age, we employed Guo and Wang's (2002) multilevel modeling approach. Three models were estimated. In model 1, random effects for task persistence were estimated by zygosity, which yielded random intercepts of .71 and .45 and random residuals of .24 and .56 for MZ and DZ twins, respectively; −2 *log likelihood* or $-2ll = 1190.0$, 486 children nested within 243 families. We calculated intra-class correlations (intercept/intercept +residual) and quantitative genetic parameter estimates; $r_{MZ} = .75$, $r_{DZ} = .45$, heritability or $h^2 = .60$, shared environment or $c^2 = .15$, nonshared environment or $e^2 = .25$.

Model 2 included child age as a fixed effect, resulting in a significant improvement in fit over Model 1 ($-2ll = 1167.5$, $X^2_{change}=1190.0-1167.5=22.5$, $df_{change} = 1$, $p <.05$); child age fixed effect = .18 ($SE = .06$). Furthermore, adding child age to the model increased the point estimate of h^2 and decreased the point estimate of c^2 ($r_{MZ} = .76$, $r_{DZ} = .41$, $h^2 = .70$, $c^2 = .06$, $e^2 = .24$), indicating that some of the shared environmental variance was attributable to age differences between families.

In Model 3, we tested the interaction between h^2 and age by including child age as a random effect. This model resulted in significant improvement in fit over Model 2 (the fixed age effect model), $-2ll = 1161.9$, $X^2_{change}=1167.5-1161.9=5.6$, $df_{change} = 1$, $p < .05$, indicating that child age moderated MZ and DZ twin similarity within families. The random estimate for age was .17 ($SE = .08$, $p < .05$), implicating a chronological age increase in the difference between MZ/DZ random effects for task persistence. In other words, child age significantly moderated the h^2 effect. This can be seen in Figure 1, in which we have plotted MZ and DZ twin intra-class correlations in age-group quartiles.

To follow up the multilevel modeling, we employed standard correlational and structural modeling analyses of the task persistence composite. Sibling similarity in task persistence was moderate, intra-class *r* (465) = .54, $p < .001$. Sibling similarity did not vary by gender or age, but did vary by zygosity; MZ *r* (89) = .74, $p < .001$, DZ *r* (135) = .45, $p < .001$, Fisher *r*-to-*z* difference test, $z = 3.38$, $p < .001$. Using variance/covariance matrices and the MX modeling program, we estimated a univariate ACE structural model (A = additive genetic variance or heritability, h^2; C = shared environment variance, c^2; E = nonshared environment variance, including measurement error, e^2; see Neale & Cardon, 1992). Model fit was acceptable, X^2 (3) = 4.775, $p = .189$, $AIC = -1.225$, $RMSEA = 0.068$, and indicated significant heritability and nonshared environment, yielding estimates very similar to those derived from the multilevel model; $h^2 = .59$ (*95% CI* = .31, .81), $c^2 = .16$ (.00, .40), $e^2 = .25$ (.19, .35).

Discussion

In the current study, we reliably assessed individual differences in task persistence based on convergent information from three independent informants (teachers, testers and observers). Principal components factor analysis suggested good internal consistency. Task persistence varied widely in this sample of 4–8-year-olds and was correlated in expected ways with being older, showing better cognitive performance and scholastic achievement, and showing fewer signs of behavioral problems. Results suggested that the multi-method and informant composite was a robust and valid construct that captured well the individual variations in task persistent behaviors in school and in the home.

Analysis of the cross-sectional data – in which we examined age as a moderator of heritability using a multilevel modeling approach – showed clear evidence of a statistically significant developmental shift from lower to higher levels of genetic variance. Among the youngest twins, similarity in task persistence was comparable for MZ and DZ twins, but MZ twin similarity was progressively higher and DZ twin similarity lower among older twin pairs. When studying the sample as a whole, the results were consistent with previous studies of children of this age (Petrill & Deater-Deckard, 2004): moderate levels of additive genetic variance, modest nonshared environmental variance and negligible shared environmental variance.

The pattern of age differences is consistent with Scarr and McCartney's (1983) theory of developmental changes in the genetic etiology of individual differences in childhood. Accordingly, heritable components of many traits (including aspects of temperament, personality and cognitive skills) become more influential as children transition to school, because they are spending more time outside of the home and are gaining more control over their own experiences. Through active and evocative gene–environment correlation, genetically influenced attributes like task persistence become more strongly reinforced by peers and non-parental adults as children increasingly seek out experiences that are consistent with their abilities and interests. For example, children who are more persistent are more likely to find task-based activities such as daily school work to be rewarding, in contrast to their peers with poor persistence.

Given that the composite included teachers' ratings, we examined whether the results would be affected by whether both twins were rated by the same teacher (because they were in the same classroom) or by two teachers (because they were in separate classrooms). Same vs. different classroom was not confounded with zygosity. Although older twin pairs were more likely to be rated by two different teachers, this was equally true for MZ and DZ twins. Furthermore, estimates of twin similarity in task persistence were the same whether the twins were rated by the same teacher ($r = .57$) or each twin was rated by a different teacher ($r = .52$). It also is important to bear in mind that the composite included tester and observer ratings as well, and those ratings always were independent for each child.

We gathered parents' reports as well, but we did not include those in the composite. Although parents' ratings of task persistence are informative for examining individual differences *between* families, previous behavioral genetic studies have shown that parents' ratings can include sibling contrast effects on measures of attention span and persistence. This may be particularly true for parent ratings of DZ twins, making analysis of such data problematic from a statistical genetics perspective (Gagne *et al*., 2003; Holmes, Hever, Hewitt, Ball, Taylor, Rubia & Thapar, 2002). In our data, we had parents' ratings on eight items that were relevant to task persistence. When included in the task persistence composite, the DZ twin intra-class correlation was −.01. The parent-ratings data alone revealed a DZ twin intra-class correlation of −.17. Rather than include parents' ratings and then statistically control for the contrast effect (an approach taken in previous studies that have used parents' reports), we instead used teachers', testers' and observers' ratings which have not been found to show a sibling contrast effect.

There are several caveats to bear in mind. Most importantly, the cross-sectional age difference in heritability of task persistence needs to be tested using longitudinal data. Fortunately, the current study includes a three-year longitudinal component. In several years, we will be able to see whether there is an increase in heritability evidenced as real change over time. Also, the data are based on twins, so the results may not generalize to non-twin children. What is needed are data from a variety of sibling studies (i.e. adoptive, step, half, full siblings) that utilize a similar multi-method and rater composite. Finally, the results may not generalize to other related behaviors or aspects of cognitive function, such as test-based measures of attention regulation or executive function. It is important not to over-interpret the results to indicate a developmental shift in heritability in attention broadly construed. Rather, the results speak to task-based persistent behavior in the home and school contexts based not on tests but on informed observers' reports.

These limitations aside, the current study shows evidence of an emergent heritable effect on individual differences in task persistent behavior. This suggests that as children make the transition into formal schooling and progress through the grade school years, non-genetic influences may be increasingly correlated with task persistent behavior as a result of active and evocative genotype–environment mechanisms (Scarr & McCartney, 1983). At the same time, nonshared environmental variance remains as an important source of variance in task persistence – environmental influences that cause sibling *differentiation* (Plomin, 1994). Future research should include longitudinal data to address whether and how the connections between task persistence and other aspects of children's behaviors and environments change with development.

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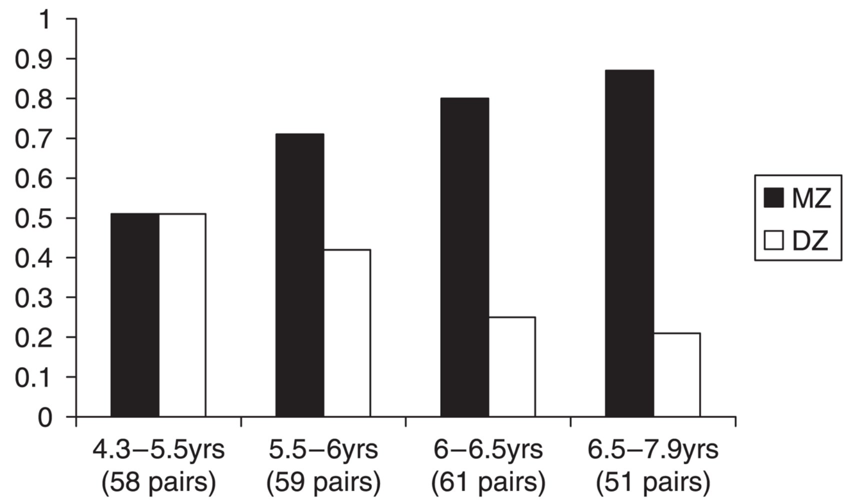

Figure 1.
Intra-class correlation for task persistence among monozygotic (MZ) twins and dizygotic (DZ) twins as a function of age quartiles: (1) 4.3- to 5½-yr-olds; (2) 5½-to 6-yr-olds; (3) 6- to 6½-yr-olds; (4) 6½- to 7.9-yr-olds.

Table 1

Factor loadings (from principal components analysis) for the six items in the task persistence composite

.77	Teacher: Cannot concentrate or pay attention (reverse-scored)
.76	Teacher: Inattentive, distracted (reverse-scored)
.73	Tester: Attends well throughout assessment
.72	Teacher: Fails to finish things (reverse-scored)
.64	Tester: Persists in tasks throughout assessment
.45	Observer: Persists and remains ‘on-task’ throughout interaction games