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Emerging Trends in Behavioral Genetic Studies of Child Temperament

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Abstract

In this article, we describe three emerging trends in the application of behavioral genetic methods to the study of temperament. The trends—using multiple methods to assess temperament, considering contextual influences on temperament, and evaluating the structure of temperament—have been well studied in the phenotypic literature, but adding a behavioral genetic perspective can enrich our understanding of temperament. We review recent behavioral genetic research in each of these areas and discuss its implications.

Keywords

temperament; behavioral genetics; individual differences

Behavioral genetics research indicates that genetic factors play a role in individual differences in children's temperaments. In this work, researchers use genetically informative samples (e.g., twins or adoptive/nonadoptive siblings) to decompose the observed (i.e., phenotypic) variance of a temperament trait into genetic, shared, and nonshared environmental variance components. *Heritability,* the genetic effect size, is the proportion of phenotypic variance that can be attributed to genetic factors. If genetic influences are important to a trait or behavior, then behavioral similarity should covary with genetic relatedness (individuals who are more genetically similar should be more behaviorally similar). For example, most temperament theories assume that temperament has a biological or constitutional foundation (1); if this is the case, then genetically identical monozygotic twins who share all of their genes should be more similar in temperament than dizygotic twins who share, on average, only half of their segregating genes.

Shared environmental variance is familial resemblance that is not explained by genetic variance and comprises environmental influences that are shared by family members, such as family demographics, one's rearing neighborhood, shared friends, or even the number of TVs or books in the house. If shared environments are important to individual differences in temperament, they should enhance the similarity of family members. *Nonshared environmental variance* is a residual variance that includes environmental influences that are

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unique to each individual. These unique environmental influences make members of the same family different from one another. Possible sources of nonshared environmental variance include differential parental treatment; relationships with friends, peers, and teachers; and nonsystematic factors such as accidents, illness, and measurement error (2).

Twin, adoption, and twin/sibling studies yield consistent evidence of genetic influences on most dimensions of temperament in early childhood, middle childhood, and adolescence. Heritability estimates range from .20 to .60, suggesting that genetic differences among individuals account for approximately 20 to 60 percent of the variability of temperament within a population (3). However, contemporary behavioral genetic studies rarely focus on heritability estimates because whether a given temperament trait is heritable is not usually the most interesting question. In this article, we describe three emerging trends in behavioral genetic studies of temperament that go beyond simple heritability estimates and may change substantially how we think about genetic and environmental influences on temperament, and perhaps temperament more generally.

Taking a Multimethod Approach

Although behavioral-genetics researchers typically assess temperament by using parent rating measures, in recent years parent ratings have been complemented by observational or lab-based measures. Different methods are thought to tap the same underlying constructs, but this is an empirical question that researchers in behavioral genetics can examine. Using many measures within the same group allows researchers to explore the extent to which different methods of assessing temperament are influenced by the same genetic and environmental factors. They can do this by using multivariate behavioral genetic analyses that explore genetic and environmental contributions to the *covariance* between multiple methods rather than the variance of each measure considered separately.

Recent research suggests that the covariance between different methods of assessing temperament is primarily due to overlapping genetic effects, but some genetic effects are also method-specific. For example, in a study of toddlers, the genetic correlation (*rG*) indexing the degree of genetic overlap between parent ratings and observational measures of inhibitory control was only moderate (*rG* =.47) indicating genetic effects unique to each measure (4). In addition, parent ratings, but not observed inhibitory control, showed substantial shared environmental influences.

Similar findings have emerged from a study of behavioral inhibition/shyness across toddlerhood: Multivariate models fit to parent and observer data at 14, 20, 24, and 36 months suggest that the two methods tap a common phenotype that is highly heritable, but that parents' ratings are also subject to unique genetic influences (5). Positive affect may be an exception to the finding of novel genetic variance for parent ratings. The genetic correlation between observed smiling and laughter in the lab and parent-rated positive affect in 2-year-old twins was 1.0, indicating that the same genetic effects influenced the two measures (6). In contrast, shared environmental influences were unique to parent ratings and accounted for most of the variance (58 percent). Despite the differences across dimensions, in all studies, the phenotypic correlation between parent and observer ratings was entirely due to genetic effects that covaried across methods (i.e., environmental influences did not covary).

These findings may be limited because the different methods were used in different situations (e.g., parent ratings in the home and observations in the lab). A twin study of toddlers' activity level assessed with multiple measures within the *same situation* (7) offers a stronger test of method-specific genetic effects, finding modest overlap between the factors (rG = .38) that influenced actigraph and parents' ratings of activity in the home. The findings suggest that both measures were genetically influenced, but the genetic effects on each measure were largely independent of each other. Again, although genetic covariance was modest, only these overlapping genetic influences contributed to the phenotypic correlation between measures.

These multimethod behavioral genetic studies indicate that genetic factors contribute both to the agreement and disagreement between different methods of assessing temperament. To the extent to which methods converge, it is due to the fact that they are tapping the same underlying genetic effects. However, agreement across methods is typically low, indicating that different methods are influenced by different factors (8). Behavioral genetics research reveals that these differences between methods arise due to both genetic and environmental influences.

Exploring Contextual Influences on Temperament

A second recent trend in behavioral genetics studies of temperament involves considering the effects of specific environments on the etiology of individual differences in temperament. Research on contextual influences has taken two approaches. The first examines *within-individual* context-specific effects by assessing children's temperament across multiple situations and evaluates the extent to which the same genetic and environmental factors operate across situations. The second involves *across-individual* contextual effects and examines measured environments as modifiers of genetic and environmental influences on temperament. Both provide unique perspectives on the interplay between genes and the environment.

Within-Individual Contextual Effects

The within-individual approach asks if genetic and environmental influences on temperament change as the individual moves from situation to situation. To control for possible method effects, the same measures of temperament must be used across situations. Twin studies of shyness and activity level illustrate situation-specific genetic effects. In studies on observed shyness in infants in the home and the laboratory, researchers found substantial genetic overlap (rG = .81) across the two situations but genetic effects specific to the home situation (9). Moreover, in a separate study of activity level in toddler twins assessed by actigraphs in home and laboratory test and play situations, results were similar (10). Genetic correlations across situations were substantial, ranging from .68 between the home and each laboratory situation to 1.0 between the laboratory test and play situations. Despite these considerable cross-situational genetic effects, genetic variance also was specific to the home environment. Approximately half of the genetic effects on activity in the home were independent of the genetic effects that influenced activity in the laboratory. The finding that the same genetic factors operated across the lab test and play situations mirrors results from a study of school-aged twins; in that study, a genetic correlation of 1.0 was reported between actigraph-assessed activity during cognitive testing and a 25-minute rest break (11). The novel genetic effects for the home but not for discrete situations within the lab illustrate that home-based measures provide additional information about temperament that might not be captured in a more artificial setting.

Contextual effects may be even subtler. The activity level of 5-month-old twins assessed while viewing televised sequences of neutral and happy facial expressions were differentially heritable depending on whether the actor was the mother or an unfamiliar female stranger (12). In the context of an unfamiliar female, genetic factors accounted for approximately 20 percent of the variance in activity level in both the neutral and happy conditions. The remaining variance was due to nonshared environmental influences. In contrast, when the same infants viewed the facial expressions of the mother (both neutral and happy), individual differences in activity were due solely to the environment, with shared environmental influences explaining 14 to 23 percent of the variance. Although not as robust, a similar pattern of modest genetic influences in the unfamiliar, but not the familiar, context emerged for social gaze and gaze aversion. Thus, even though the physical situation or tasks did not differ, the etiology of temperamental dimensions was not the same in the context of different actors.

Across-Individual Contextual Effects

Rather than looking at short-term situational change and the genetic and environmental overlap across situations *within* individuals, the second approach considers more enduring environments and tests for differences in the magnitude of genetic and environmental influence *across* individuals who experience varying levels of a measured environment. Behavioral genetics researchers refer to this as a *genotype-environment interaction* (GxE). The handful of studies exploring environmental moderators of genetic and environmental influences in children's temperament provides novel evidence of the importance of environmental influences on individual differences in temperament.

Parenting and global aspects of the home environment moderate genetic and environmental influences on temperament. Genetic factors accounted for most of the variance in anger proneness for toddler twins who experienced much maternal negativity, but shared environmental factors accounted for most of the variance for twins who experienced less maternal negativity (13). Similarly, in middle childhood, both surgency/extraversion and effortful control were more heritable in homes that were more chaotic, and negative affectivity was more heritable in homes that had less optimal physical environments (i.e., crowded or unsafe; 14). In children, temperament may be more heritable under adverse environments, but in adolescent twins, the opposite pattern emerged. Genetic effects on both positive and negative emotionality were greater for those adolescents who rated their relationship with their parent as characterized by high levels of regard/warmth (15). At lower levels of regard/warmth, genetic influences diminished and the relative influence of the nonshared environment increased. Conflict within the parent-child relationship also moderated genetic influences on negative emotionality; as conflict increased, the relative impact of genetic influences decreased and the importance of the shared environment increased.

Although the direction of effects is inconsistent across studies of GxE interactions in children and adolescents, this work suggests a dynamic interplay between the environment and sources of variation in temperament that might be more satisfying to developmentalists who are often dismayed by the lack of familywide environmental influences on temperament. Shared environmental influences may be important for some individuals but may not be apparent in basic twin analyses because the analyses represent average estimates of genetic and environmental effects collapsing across all levels of unmeasured contexts (15).

Examining the Structure of Temperament

Until recently, little research has considered the structure of temperament from a behavioral genetics perspective. This may reflect the field of temperament more generally because, unlike in adult personality where there is general agreement about structure, researchers tend to disagree about the basic units of temperament (16). Most behavioral genetics research on temperament has been at the level of lower-order dimensions (e.g., activity level); however, as a hierarchical organization of temperament has become more prominent in the phenotypic literature, researchers have become more interested in genetic and environmental influences on individual differences in higher-order factors of temperament such as surgency/ extraversion, negative affectivity, and effortful control. Twin studies of temperamental effortful control in toddlers (17), school-aged children (14, 18–20), and young adults (21) consistently find substantial genetic and negligible shared environmental influences, whether assessed via parent report, behavioral observations, or self-report. When rated by parents, surgency/extraversion shows a similar pattern of significant genetic effects and nonsignficant shared environmental influences (14, 17, 19, 20), but observer ratings suggest that both genetic and shared environmental influences contribute to familial resemblance in surgency/extraversion (22, 23). Parent ratings of negative affectivity also show a consistent pattern of significant genetic influences across age, but evidence for shared environmental influences is mixed—even within the same sample (17, 19, 20). For example, shared environmental influences have been found for fathers’ ratings, but not mothers’ ratings (21), reminding us once more that methods matter.

These findings of genetic and environmental influences on higher-order temperament dimensions do not address fundamental questions regarding the structure of temperament. To what extent do the lower-order traits that load on a higher-order dimension share common genetic and environmental underpinnings? Multivariate analyses of the genetic and environmental overlap between lower-order traits can provide clues to whether the phenotypic structure of temperament reflects the underlying genetic structure. Although researchers have not examined this in children, a study of effortful control in adults suggests that this might be the case. The genetic correlations between subscales of effortful control ranged from .64 between inhibitory control and activation control to .93 between inhibitory control and attentional control, indicating that the three subscales are largely influenced by the same genetic factors (21). Environmental correlations (nonshared) were only moderate, suggesting genetic coherence between the dimensions that constitute the higher-order dimension of effortful control. At issue is whether a similar pattern will emerge for other higher-order dimensions (e.g., negative affect or surgency/extraversion) and in younger samples.

Genetic influences also covary between separate higher-order dimensions, although more modestly. The genetic correlations among positive affect/surgency, negative affect, and effortful control in middle childhood ranged from .17 to .51 (19). In contrast to these modest overlapping genetic influences, the nonshared environmental influences overlapped completely across all three dimensions and there was considerable shared environmental covariance (rC = .89) between negative affect and effortful control. The genetic and environmental overlap between lower-order dimensions that load on *different* higher-order temperaments show a similar pattern. The genetic correlations among approach/positive anticipation and frustration/anger (24), task persistence and frustration/anger (25), and anger and inhibitory control (26) were, at best, only moderate, whereas the correlations between environmental factors across dimensions were substantial. More research is needed, but these findings of greater genetic convergence within, than between, higher-order dimensions are consistent with theories of temperament that propose that separate, but interrelated, neural substrates underlie higher-order temperament dimensions (27).

Implications

The behavioral genetic findings we have reviewed are relevant to researchers who study temperament from a phenotypic perspective. The multimethod findings highlight important issues regarding the measurement of temperament. The fact that different measures of the same temperament dimension have different etiologies means that researchers should not assume that all measures of temperament are interchangeable. Alternatively, a lack of agreement across methods may not simply reflect measurement error (i.e., measure-specific genetic and shared environmental effects are independent of measurement error). Findings with one method may not generalize to another because different methods tap different processes. Therefore, it is not surprising to find that different methods yield different developmental patterns (e.g., 28) or associations with developmental outcomes (26, 29). Relying on a single assessment method may not allow a full understanding of temperament and the factors that underlie variations in temperament across children. More generally, these findings have important implications for issues of replication, a topic that is becoming increasingly relevant in psychology. When measures differ across studies, failures to replicate may reflect differences in the underlying etiologies of methods assumed to assess the same trait.

Similarly, findings of context-specific genetic effects suggest that different situations provide different views of temperament. Diverse situations likely place different demands on the individual, elicit different behaviors, and consequently, engage different genetic influences on processes relevant to each context. Because the genetic and environmental influences that underlie individual differences in temperament may vary across situation, researchers should consider carefully the context in which temperament is assessed.

Moreover, these findings provide a unique perspective on situations: Behavioral differences across situations can have a genetic basis and consequently, contextual differences are not necessarily environmental in origin.

GxE analyses permit a more nuanced understanding of the etiology of temperament, and reveal novel evidence of direct and indirect environmental influences on temperament. Shared environments may directly influence individual differences in temperament under certain contexts (e.g., when the child experiences more positive parenting). Environments can also indirectly influence temperament by modulating the expression of children's genetically influenced temperaments, thereby potentially enhancing or diminishing children's genetically based vulnerability for later emotional and behavioral problems. This adds an interesting twist to the notion of differential sensitivity, which suggests that some temperaments may be more responsive to the environment (30). The GxE findings we have reviewed suggest that temperamental differential susceptibility might arise from specific environmental experiences.

Behavioral genetics research can also inform the structure of temperament. Factor analytic studies of temperament have indicated a hierarchical structure of temperament (31). The use of genetically informative samples can reveal the extent to which this structure is based in biology. Although research on the structure of temperament has just begun, findings hint that, as is the case with the study of adult personality (32), the phenotypic architecture of temperament reflects its underlying genetic structure. Facets that load on the same higher-order dimension are largely influenced by the same genetic factors, whereas different dimensions are more genetically distinct. These results provide early evidence that dimensions of temperament are genetically coherent, and that the structure of temperament has a biological basis and is not simply a statistical phenomenon.

Conclusions

The research we have described here reveals that behavioral genetic research has provided powerful insights into issues related to the measurement of temperament, contextual effects and environmental moderators of genetic effects on temperament, and the underlying structure of temperament. These are just a few areas in which our knowledge of temperament can be enriched by applying a behavioral genetics approach. Clearly, behavioral genetics research has much more to offer developmentalists than simple heritability estimates.

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