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Exploring links among imitation, mental development, and temperament

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Abstract

Links among imitation, performance on a standardized test of intellectual development, and laboratory-assessed temperament were explored in 311 24-month old twin pairs. Moderate phenotypic associations were found between imitation, mental development, and temperament dimensions of Affect/Extraversion and Task Orientation. Covariance between imitation and mental development reflected genetic and shared environmental influences, whereas associations between imitation and temperament reflected genetic, shared, and nonshared environmental influences. Genetic factors linking imitation and temperament were the same as those linking temperament and mental development. Nonetheless, approximately 62% of total genetic variance on imitation was independent of genetic influences on mental development and temperament, suggesting that young children's imitation is not simply an index of general cognitive ability or dispositional style but has many underlying genetic influences that are unique.

Keywords

IMITATION; MENTAL DEVELOPMENT; TWINS; TEMPERAMENT; BEHAVIOR GENETICS

The capacity to mimic observed behaviors is an early emerging skill that is thought to reflect various facets of social cognition (McEwen, Happe, Bolton, Rijdsdijk, Ronald, Dworzynski, & Plomin, 2007; Forman, Aksan, & Kochanska, 2004; Meltzoff & Decety, 2003). As such, young children's imitation is often assessed as an indicator of early intellectual and social development. However, despite wide-ranging theoretical and empirical interest, relatively little is known regarding the mechanisms underlying these apparent connections. The present study seeks not only to further elucidate phenotypic links among imitation, mental development, and temperament, but to investigate the relative contributions of genetic and environmental factors to these associations.

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Imitation and Mental Development

Research over the past century has examined children's imitation for its reflection of various key features of mental development, including recall memory (e.g., Piaget, 1962; Barr, Dowden, & Hayne, 1996; Cheatham, Bauer, & Georgieff, 2006), observational learning (e.g., Bandura, Ross, & Ross, 1961, 1963), understanding of intentions and Theory of Mind (e.g., Hanna & Meltzoff, 1993; Carpenter, Call, & Tomasello 2002; Gergely, Bekkering, & Kiraly, 2002). Elicited imitation paradigms have been, and continue to be, used in research tapping these aspects of normative mental development, and are generally found to be quite effective means for assessing such abilities.

Imitation serves as a particularly important and efficient learning mechanism during early infancy and childhood. Twelve-to eighteen-month old infants can acquire up to one to two new behaviors per day through imitation (Barr & Hayne, 2003), and even prior to the age when infants begin to comprehend verbal instruction, they may derive skills and behavioral patterns through observation and subsequent mimicry of another's actions (Meltzoff & Moore, 1997). Children's abilities to imitate increasingly complex behaviors are well-developed by early toddlerhood; thus much imitation research is focused on children in this age range. However, little, if any, research has sought to explore the relation between children's imitation and direct measures of intellectual performance.

Imitation and Temperament

Though some contention remains among developmentalists regarding the nuances of 'temperament' (e.g., Goldsmith, Buss, Plomin, Rothbart, Thomas, & Chess, 1987), most generally agree that temperament comprises relatively stable individual differences in patterns of social and emotional responding. Assessments of temperament typically include behaviors related to sociability, attention, activity level, reactivity, mood, and emotional control (e.g., Thomas & Chess, 1977; Buss & Plomin, 1975; Goldsmith & Campos, 1982; Rothbart & Bates, 2006). There is evidence to suggest that individual differences in children's imitation may be linked to temperament-driven aspects of interpersonal and social functioning (e.g., Uzgiris, 1981; Roberts, Wurtele, Boone, Metts, & Smith, 1981; Learmonth, Lambert, & Rovee-Collier, 2005), and research with neonates and young infants has demonstrated links between early facial imitation and measures of activity level and attentiveness (Heimann, Nelson, & Schaller, 1989; Heimann, 1989, 1998, 2001, 2002). However, while there is empirical support for the idea that performance on multi-step motor imitation tasks remains stable across infancy and early toddlerhood (e.g., Heimann & Meltzoff, 1996; Sakkalou, Ellis-Davies, Fowler, Hilbrink, & Gattis, 2013), it is not known whether facial imitation in early infancy predicts later performance on more complex motor imitation tasks, so it is possible that the associations of facial imitation with activity level and attentiveness may be exclusive to that particular imitative domain.

Of the few studies to examine links between motor imitation and temperament-like characteristics in young children, an early investigation found that 36 month-old children rated as 'extroverts' reproduced more modeled behaviors than those rated as 'introverts' (Fouts & Click, 1979), while more recent research with toddlers (McEwen et al, 2007)

revealed some modest positive associations between 24 month-old children's elicited imitation and what has been termed 'socially insightful behavior' (e.g., parent ratings of emotional responsiveness and empathy). Such findings provide further support for a connection between imitation and temperament-like traits in early childhood; however, it should be noted that the measure of elicited imitation used in the latter study relied on parent-administered items that explicitly requested imitation of the children, potentially confounding imitation with other behavioral or temperamental attributes such as compliance, and used the same (parent) rater for both twins, introducing the possibility for rater bias.

A more recent longitudinal study of infants from 12 to 15 months of age found an association between the temperament characteristic of surgency (thought to be a precursor to extraversion) and tendencies to imitate non-essential features of goal-directed actions, strengthening the idea that, at least for young infants, 'faithful' imitation may be indicative of early-emerging social motivation (Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013). As the authors of that study acknowledge, however, determining the nature and direction of this association between imitation and temperament is limited by the study's small sample size, highlighting the necessity for further research in this area.

Behavior Genetic Research

Despite some noted sampling and methodological limitations of prior research, findings of covariance between young children's imitation and cognition or temperament-related variables are of particular interest from a behavioral genetics perspective. Twin studies find that individual differences in toddlers' imitation are due in large part to genetic influences (Fenstermacher & Saudino, 2007; McEwen et al., 2007). One study of 24-month old twins' performance on several multi-step imitation tasks found that genetic factors explained over 40% of the variance in overall imitation (Fenstermacher & Saudino, 2007). The remaining variance in imitative behavior was due to nonshared environmental influences. Although specific sources of nonshared environment vary and were not specifically investigated in the aforementioned research, these can include differential experiences such as independent social relationships, physical encounters, or opportunities for learning that serve to make family members differ from one another on a particular trait or ability. These stand in contrast to shared environmental influences, experiences shared by family members which, along with genetic influences, would serve to make them appear more similar.

Given the known associations of imitation with many key features of early cognitive and social development, the aforementioned behavior genetic findings beg the question of the extent to which correlations of imitation with mental development and temperament at the behavioral level reflect similar underlying genetic and environmental influences. For example, it is possible that many of the same genes that influence an individual's propensity to imitate also influence that individual's performance on a test of mental ability or tendency to display certain traits (i.e., overlapping genetic influences), and/or that the same environmental factors that influence imitation (for example, history of parental encouragement or other types of reinforcement) also influence intellectual performance or aspects of temperament (i.e., overlapping environmental influences). Though no research has

directly examined underlying genetic and environmental contributions to the covariance between imitation and objectively-measured mental ability, behavior genetic studies suggest that these variables may share some genetic and environmental underpinnings. It is by now quite evident that intelligence is influenced by genetic factors (e.g., Plomin et al., 2001), and given the finding of an association between genetic factors operating on imitation and vocabulary (McEwen et. al, 2007), it is plausible that mental task performance may share genetic and environmental influences with imitation. Similarly, behavior genetic studies have found many aspects of temperament to be moderately heritable (Goldsmith et al, 1987). For example, observer-rated Affect/Extraversion, Attention/Persistence and Activity Level in early childhood consistently show genetic influences (Matheny, 1980; Braungart et al., 1992; Saudino, Plomin, & DeFries, 1996). Moreover, some modest genetic overlap has been found between parent-ratings of ‘socially insightful behavior’ and elicited imitation in young children (McEwen et al, 2007), lending further support to the idea that phenotypic relations between elicited imitation and related dimensions of temperament may reflect common genetic factors.

The Present Study

The present study expands upon current knowledge of the etiology of young children’s imitation by examining the possible covariance of multi-step elicited imitation performance with objective laboratory assessments of intellectual performance and temperament. Where significant phenotypic relations were found, multivariate quantitative genetic models were applied to examine the degree to which these relations reflect common genetic and environmental influences across constructs. In light of imitative behavior’s prominent role in early sociocognitive development, it was predicted that significant associations would emerge at both the phenotypic and behavior genetic levels. More specifically, we predicted that, given the demonstrated role of imitation as a mechanism for learning, children who scored higher on measures of elicited imitation would evince stronger performance on measures of mental development. We additionally predicted, based on findings suggesting that attention and social engagement are associated with imitative performance, and because of the inherently social nature of the imitation paradigms used, that children who were more socially outgoing and attentive in the laboratory environment would show higher performance on measures of elicited imitation. Because this is the first study to investigate analysis of these predicted associations at the behavior genetic level, we made no specific predictions with regard to the genetic and environmental factors underlying these behaviors. However, given the moderate heritabilities for elicited imitation, MDI, and temperament found in prior research, it was expected that phenotypic correlations observed between these variables might to some extent reflect similar genetic and environmental influences.

Method

Sample

Data from three hundred and eleven same-sex (143 MZ, 168 DZ) 24 month-old twin pairs was included in the present study, derived from an initial sample of 315 (exclusion criteria for the four pairs of twins whose data was not included is described later in this section).

Because pairs of MZ, or monozygotic (identical) twins, who are necessarily same-sex, were directly compared to pairs of DZ, or dizygotic (fraternal) twins, only same-sex DZ twin pairs were included in the present study. Families were recruited via mail and telephone from the greater Boston area based on birth records obtained through the Massachusetts Department of Vital Statistics by the Boston University Twin Project. Mean age of the sample at the time of assessment was 2.07 years ($SD = .05$). The sample was predominantly white and middle class, and was generally representative of the population of the greater Boston area. Of those families reporting race ($n = 309$ families), 87% were Caucasian, 8% Mixed Race, 3% African American, 2% Asian, and less than 1% Native American. The reported ethnicity of the sample ($n = 307$ families reporting) was 5% Hispanic or Latino and 95% non-Hispanic/Latino. Socioeconomic status (SES) of the sample was computed using the Hollingshead Four-Factor Index of Social Status (Hollingshead, 1975). Socioeconomic status according to the Hollingshead Four Factor Index (1975) ranged from low to upper middle class (range=14.5–66; $M = 51.04$, $SD = 10.68$).

Prior to participation, all twins were preferentially screened to exclude children who were not of normal birth weight (e.g., not less than 1750 grams) or gestational age (e.g., at least 34 weeks gestation), or who presented with developmental issues (e.g., known chromosomal abnormalities) that might affect their behavioral assessments or task performance. This resulted in the exclusion of four twin pairs from our original sample of 315 sets of twins. Zygosity was determined by DNA cheek swab analyses. In instances where the results of the DNA analyses were not available ($n = 3$ twin pairs), zygosity was assessed using parent reports of twins' physical similarity and instances of identity confusion. Zygosity classification via parent reports has been found to be very reliable when compared with the results of DNA screenings (Goldsmith & Campos, 1990). In the present sample, the agreement, as indicated by Cohen's kappa, between zygosity assessed through DNA analyses and parent questionnaires was .94 ($p < .0001$). Moreover, 97% of twins identified via parent ratings were found to have been identified correctly when checked against DNA results.

Procedure

Twins completed 2 one-hour laboratory visits scheduled approximately 48 hours apart. Each member of the twin pair was individually assessed in one of two situations during the visits. On the first visit, one of the twins participated in a standardized test of mental development (BSID-II; Bayley, 1994), while the other twin participated in a laboratory play situation that included three multi-step, experimenter-modeled elicited imitation tasks: (1) the *Puppet Task*, derived from Barr et al. (1996), a three-step procedure wherein an adult experimenter models removing, shaking, and replacing a mitten on a puppet's hand; (2) the *Birdhouse Task*, adapted from Carpenter et al. (2002), a seven-step task wherein the experimenter twists and removes a wooden pin from the side of a wooden birdhouse, opens the front door of the birdhouse, removes a toy bird from inside the birdhouse, and performs vocal and gestural behaviors with the toy; and (3) the *Rattle Task*, also derived from Barr et al. (1996), a three-step task wherein the experimenter models dropping a ball into a jar, attaching a handle to the jar, and shaking it (see Fenstermacher & Saudino, 2007, for details). The three imitation tasks were presented in direct succession in the order indicated above. At the

second visit, the situations were reversed. Thus, the mental development and imitation assessment protocols were administered on separate days for each twin and within each pair, twins were assessed by different testers. All sessions were videotaped. At the conclusion of each of the two visits, testers completed temperament measures.

Measures

Composite Elicited Imitation Score—Responses on the elicited imitation tasks were scored online (in situ) by the administering experimenter. Participants received one point for each imitated step of each task, with an additional point added for each task if the behaviors were performed in the correct sequence. This yielded scores ranging from 0–4 for the Puppet ($M = 2.02$; $SD = 1.53$) and Rattle ($M = 2.73$; $SD = 1.06$) tasks and 0–8 for the Birdhouse task ($M = 4.29$; $SD = 2.41$). Figure 1 depicts the score distributions for each of the three multi-step elicited imitation tasks. A composite elicited imitation score was derived by summing the total points received for each of the three multi-step elicited imitation sequences (see Fenstermacher & Saudino, 2007). The maximum possible composite elicited imitation score was 16. This method of scoring yielded a reasonably normal distribution, as depicted in Figure 2. To determine the reliability of this scoring method, videotapes of a subsample ($n = 140$ children) were coded by trained research assistants who had not previously worked with the children. Interrater reliability between the online and videotape coding for all three tasks was found to be high, with intraclass correlations ranging from .90 to .97 ($p < .001$). Interrater means and standard errors for each dimension of each task can be found in Table 1.

Mental Development—The Bayley Scales of Infant Development-Second Edition (BSID-II; Bayley, 1994) were administered to obtain a standardized assessment of mental development. The BSID-II is a well-established reliable and valid measure of cognitive ability that yields a Mental Development Index (MDI) score. The MDI assesses children's general intellectual abilities in a variety of domains, including vocabulary, spatial development, and memory. Sample items for 24-month old children include naming objects, counting, selecting a previously seen picture from a group of similar pictures, and matching colors.

Observer-Rated Temperament—Following each test session, examiners completed the Infant Behavior Record (IBR; Bayley, 1969). The IBR is a frequently used observer-rated measure of temperament in behavioral genetic research. The measure contains 30 items describing behaviors observed during the assessment. Factor analyses has yielded three temperament dimensions: Activity, Affect/ Extraversion, and Task Orientation (Matheny, 1983). The Activity dimension assesses infants' general levels of movement and energy during the test situation; Affect/Extraversion assesses social responsiveness, cooperativeness, and emotional tone; and Task Orientation taps attention span, persistence, goal directedness, and responsiveness to the testing stimuli. The IBR has demonstrated good reliability and validity and assesses a range of temperament items appropriate for the ages studied (Nellis & Gridley, 1994). For each temperament dimension, the standardized unweighted items were aggregated and averaged across the two laboratory episodes. Internal consistency as indicated by Cronbach's alpha was high (i.e., above .90 for all three IBR

factors). Intraclass correlations (ICC) indexing inter-rater agreement ranged from .62 for Affect/Extraversion and .63 for Task Orientation to .69 for Activity ($p < .001$).

Analyses

Correlational analyses—Phenotypic correlations were calculated to assess the strength of the observed relations of composite elicited imitation scores to mental development and temperament. When significant phenotypic covariance was found, cross-twin cross-trait correlations were computed. Cross-twin cross-trait correlations estimate the relation of one twin's performance on one measure (e.g., elicited imitation) with his or her co-twin's performance on the other (e.g., MDI). Genetic covariance between variables is suggested when the cross-twin cross-trait correlations for MZ twins exceed those for DZ twins.

Model-fitting analyses—Multivariate model fitting analyses were used to estimate genetic and environmental sources of variance for each variable and genetic and environmental contributions to the *covariance* between variables (i.e., the extent to which common genetic and environmental factors operate on elicited imitation and the related variables). The multivariate model allows for the estimation of the degree of overlap among genetic and environmental influences on multiple phenotypes (i.e., genetic and environmental correlations) and of genetic and environmental contributions to the phenotypic correlation between performance on different tasks (i.e., the extent to which these overlapping influences individually explain the phenotypic correlation between variables). In the present study a multivariate Cholesky model was fit to the data. Because the variables in the model were, in part, determined by the phenotypic associations between variables, the model will be described in more detail in the Results section.

Results

Descriptive Statistics

Table 2 lists the means and standard deviations for composite elicited imitation scores, Bayley MDI, and the IBR temperament dimensions of Activity, Affect/Extraversion, and Task Orientation by gender and zygosity. To account for dependence in the data due to the fact that the sample comprised pairs of twins, the significance of the main effects of sex and zygosity and the sex x zygosity interactions were estimated for each variable using generalized estimating equations (GEE) implemented in the SAS GENMOD procedure. GEE are an extension of the standard generalized linear models that allow modeling of correlated data (Liang & Zeger, 1986; Zeger & Liang, 1986). Neither the main effects of sex, zygosity, or the sex x zygosity interaction were significant for any of the five variables (Table 2). Additionally, saturated model comparisons of MZ and DZ twin groups in Mx (Neale, 1997) revealed no significant differences in total variances for any of the variables, thus fulfilling a basic assumption of the twin method.

Phenotypic Correlations

Table 3 presents the phenotypic correlations between composite elicited imitation, MDI, and temperament assessed on the IBR. To correct for the nonindependent nature of the data at the phenotypic level, correlations and their p -values were calculated using Griffin and

Gonzalez's method for calculating dyadic-level correlations using the PROC IML command in SAS. This method takes into account the paired nature of the data and calculates overall correlations by combining both dyad-level and individual-level effects (Griffin & Gonzalez, 1995), and is an appropriate and conservative method for estimating phenotypic correlations using twin data (Kenny, Kashy, & Cook, 2006; O'Connor, 2004).

The moderately strong phenotypic associations between elicited imitation and MDI suggest that children with higher intellectual performance tend to imitate more frequently. Temperament also yielded moderate associations with elicited imitation performance. Children exhibiting more extroverted behavior in the laboratory tended to perform better on the imitation tasks than children rated as less extroverted. Perhaps not surprisingly, attention also showed a moderate positive association with overall elicited imitation scores, indicating that children who were able to sustain their interest and to remain focused and attentive to laboratory tasks tended to imitate more in the elicited paradigms. Activity level was not significantly associated with imitation and therefore was not considered in further analyses.

Twin Intraclass Correlations and Cross-Correlations

Twin intraclass and cross-correlations are presented in Table 4. Twin intraclass correlations describe the average correlation between members of each twin pair for a particular behavior or trait; genetic influence on that behavior or trait is implied when MZ interclass correlations significantly exceed DZ interclass correlations. Cross-correlations refer to correlations between one twin's score on one measure and his or her co-twin's score on another. Cross-correlations provide information on potential for overlapping genetic or environmental influences on different behaviors or traits. For the present sample, MZ intraclass correlations significantly exceeded DZ correlations for elicited imitation, MDI, Affect/Extraversion, and Task Orientation, indicating genetic influences on all four variables. In addition, the pattern of cross-twin cross-trait correlations between elicited imitation and MDI strongly suggested the presence of genetic covariance, with MZ cross-correlations substantially exceeding DZ cross-correlations. Cross-correlations between elicited imitation and temperament hinted at the possible presence of genetic covariance, though the pattern of results suggested that the majority of the phenotypic overlap between elicited imitation and Task Orientation or Affect/Extraversion could be explained by environmental factors. For all three variables, DZ cross-correlations were greater than $\frac{1}{2}$ MZ cross-correlations, hinting at shared environmental covariance.

Multivariate Model-Fitting Results

To examine the relative contributions of common genetic and environmental factors to the observed covariance between elicited imitation, mental development, Affect/Extraversion and Task Orientation, a quadrivariate Cholesky model was fit to the raw data in Mx (Neale, 1997). This model is depicted as a path diagram in Figure 2. The model decomposes the phenotypic variances and covariances of the MDI, Task Orientation, Affect/Extraversion, and elicited imitation into genetic and environmental variance that is common to all four measures (A_4 , C_4 , E_4); common to Task Orientation, Affect/Extraversion, and elicited imitation independent of that common to all four factors (A_3 , C_3 , E_3); common only to

Affect/Extraversion and elicited imitation (A_2 , C_2 , E_2); and that is unique to elicited imitation (A_1 , C_1 , E_1).

The A_{44} and A_{41} paths represent the genetic covariance between the MDI and elicited imitation. Covariance between imitation and Task Orientation can be mediated through the A_4 factor (paths A_{43} and A_{41}) and the A_3 factor (paths A_{33} and A_{31}). Similarly, the covariance between imitation and Affect/Extraversion can be mediated through factors A_4 (paths A_{42} and A_{41}), A_3 (paths A_{32} and A_{31}) and A_2 (paths A_{22} and A_{21}). The corresponding C and E paths represent shared and nonshared environmental sources of covariance, respectively. The paths leading from the factors A_1 , C_1 , and E_1 represent any unique genetic or environmental influences on elicited imitation that are independent of temperament and mental development.

In this model, heritability (a^2) is calculated as the sum of all squared standardized A path coefficients leading to the phenotype of interest. For example, the heritability of elicited imitation is calculated by squaring the A_{41} , A_{31} , A_{21} , and A_{11} paths and then summing the results. The same principles can be applied to standardized C and E path coefficients to derive the proportions of variance due to shared and nonshared environmental influences, respectively. In addition, the extent to which the same genetic and environmental influences contribute to the phenotypic covariance between those variables can be estimated by multiplying the path coefficients between two variables within a factor and summing across factors common to both phenotypes. For example, in Figure 2, the genetic contribution to the phenotypic correlation between elicited imitation and MDI can be estimated by multiplying the coefficients from the A_{44} path leading to MDI and the A_{41} path leading to elicited imitation. Following the same logic, the genetic contribution to the phenotypic correlation between Task Orientation and elicited imitation would be estimated by multiplying the A_{44} and A_{42} paths and adding this number to the product of the A_{33} and A_{31} paths, as covariance between elicited imitation and Task Orientation can be mediated through both the MDI and Task Orientation factors in the quadrivariate model. Estimates of environmental contributions to phenotypic covariance between variables can be calculated in the same manner using the C and E path coefficients.

The overall fit of a model can be assessed by calculating twice the difference between the negative log-likelihood ($-2LL$) of the model and that of a saturated model (i.e., a model in which the variance/covariance structure is not estimated and all variances and covariances for MZ and DZ twins are estimated). The difference in $-2LL$ is asymptotically distributed as χ^2 with degrees of freedom equal to the difference in the number of parameters in the full ACE model and that in the saturated model.

The path diagrams in Figure 4 present the parameter estimates and 95% confidence intervals for the full model. The additive genetic, shared environmental, and nonshared environmental parameters are presented separately for clarity. The full model adequately fit the data (Saturated model $-2LL = 9264.36$, $df = 2369$; Full model $-2LL = 9321.04$, $df = 2411$, $\chi^2 = 56.67$, $df = 42$, $p = .07$, $AIC = -27.33$); however, several nonsignificant paths were estimated at zero or near zero and could be dropped from the model without a significant decrement in

fit (Reduced model: $-2LL = 9323.37$, $df = 2431$, $\chi^2 = 59.01$, $df = 53$, $p = .27$, $AIC = -46.99$; difference between Full and Reduced models: $\chi^2 = 2.34$, $df = 11$, $p = .99$).

Figure 5 depicts the path estimates for the reduced model. The significant parameter estimates for the A_4 factor indicate that there are genetic influences common to the MDI, Task Orientation, Affect/ Extraversion, and elicited imitation. For the A_3 factor, only the paths leading to Task Orientation and Affect/Extraversion were significant, indicating that these two aspects of temperament share some overlapping genetic influences beyond what is common to the MDI. However, other than the paths from the A_4 factor, no significant genetic paths were found between Task Orientation and elicited imitation or between Affect/ Extraversion and elicited imitation, suggesting that elicited imitation does not share any common genetic influences with the temperament factors over and above what is common to mental development. Interestingly, the A_1 unique parameter indicated substantial unique genetic influences (62% of the total genetic variance on elicited imitation) independent from those operating on mental development or temperament. Shared environmental influences were significant and covaried between all four variables. That is, all shared environmental effects on elicited imitation and temperament was mediated through the first factor (C_4), with no shared environmental covariance between Task Orientation and Affect/Extraversion or between either of the temperament factors and elicited imitation over and above that shared with the MDI.

Although there were nonshared environmental influences in common to the three Bayley measures (i.e., the MDI and IBR Task Orientation and Affect/Extraversion), no common nonshared environmental influences were found to contribute to the relation between elicited imitation and mental development. The observed covariance between elicited imitation and the MDI can be attributed to a combination of common additive genetic and shared environmental influences. There were, however, common nonshared environmental factors contributing to the covariation between Task Orientation, Affect/Extraversion and elicited imitation. Thus temperament and elicited imitation share some common nonshared environmental factors unique from those contributing to mental development. Finally, the E_1 nonshared environmental factor was significant, indicating substantial nonshared environmental influences operating on elicited imitation that are unique from those operating on mental development or temperament.

Variance components—Table 5 presents the genetic and environmental variance components from the reduced model. All four variables demonstrated significant heritability. Genetic factors accounted for nearly half of the total variance in MDI, approximately one third of the variance in Task Orientation and elicited imitation, and nearly a quarter of the variance in Affect/Extraversion. Shared environmental factors made a relatively substantial contribution to the variance observed in MDI, but contributed only modestly to individual differences in elicited imitation or temperament. Thus, cotwin resemblance for mental ability is due to roughly equal contributions of additive genetic and shared environmental factors, whereas resemblance for elicited imitation is largely due to additive genetic factors. Nonshared environmental factors accounted for the remaining variance, explaining most of the environmental variance underlying elicited imitation, Task Orientation, and Affect/ Extraversion.

Genetic and environmental correlations—Genetic and environmental correlations between variables are presented in Table 6. These correlations indicate the degree to which the *same* underlying genetic and environmental factors operate on two variables (please see Posthuma, 2009, for further description of genetic and environmental correlations). Because the genetic correlation is independent of heritability, a genetic correlation may be high even where heritabilities are low. That is, two modestly heritable traits may have a high genetic correlation if they are influenced by the same genes. Similarly, two highly heritable traits would show a zero genetic correlation if completely different genetic factors influenced them. Again, this logic also extends to environmental correlations and explains why in our analyses we find that although shared environmental influences were modest for temperament and imitation, the shared environmental correlation between these variables is 1.0.

The genetic correlation of .62 between elicited imitation and MDI indicates that 62% of the genetic influences operating on elicited imitation are shared with those operating on mental development; whereas approximately one half of the genetic influences on imitation overlap with those influencing temperament. The genetic correlations between the MDI, Task Orientation, and Affect/Extraversion were high (ranging from .73 to 1.0), suggesting that many of the same genetic factors underlie these 3 components of the Bayley. The shared environmental correlations of 1.00 between elicited imitation and the MDI and both temperament dimensions indicates that all of the (negligible) shared environmental influences operating on elicited imitation overlap with those operating on mental development and temperament. Finally, although nonshared environmental correlations between the three Bayley measures (MDI, Task Orientation and Affect/Extraversion) were significant, only Task Orientation showed a substantial nonshared environmental correlation with elicited imitation.

Genetic and environmental contributions to phenotypic correlations—Estimates of genetic and environmental contributions to the phenotypic correlations between variables are depicted in Figure 6. These estimates provide an index of the relative contribution to the total observed phenotypic covariance between two variables that can be attributed to genetic, shared environmental, and nonshared environmental factors. As indicated in Figure 6, although shared environmental influences on elicited imitation were minimal, they explain approximately half of the total phenotypic correlation between elicited imitation and mental development. The remainder of the covariance between elicited imitation and mental development is due to genetic factors that influence both behaviors. The phenotypic correlation between elicited imitation and Task Orientation is due to relatively equal distributions of genetic, shared, and nonshared environmental factors. The phenotypic correlation between elicited imitation and Affect/Extraversion can also be attributed to genetic, shared, and nonshared environmental factors, although the contribution of nonshared environmental influences is more modest.

Summary of results—Elicited imitation is correlated at the phenotypic level with mental performance (as assessed by the Bayley MDI) as well as the laboratory-assessed IBR dimensions of Task Orientation and Affect/Extraversion. These phenotypic correlations are

explained in part by overlapping genetic and environmental influences. Multivariate model-fitting and correlational analyses reveal that many of the same genetic factors that underlie performance on the Bayley MDI influence both the temperament factors of Task Orientation and Affect/Extraversion and elicited imitation performance. At the same time, a significant portion of the genetic variance operating on elicited imitation was found to be unique from that operating on the other variables. Though shared environmental factors were not found to contribute substantially to elicited imitation performance, what little shared environment was found came entirely through the MDI – that is, the same shared environmental factors that serve to influence twins' MDI performance also influence their temperament scores and performance on the imitation tasks. Finally, though some nonshared environmental influences were found to be common to both Task Orientation and imitation, none of the nonshared environmental influences operating on imitation were found to be shared with MDI.

Discussion

Prior studies of imitative behavior in young children suggest links between this capacity and aspects of temperament and mental ability. The present research sought to extend these findings by directly comparing imitative performance with standardized measures of mental ability and temperament, and by broadly examining the underlying sources of covariance between these domains. The moderate phenotypic covariances between imitation, mental ability, and temperament found in the present study indicate that young children's propensities to use imitation as a means for learning or social interaction may to some extent reflect the same underlying aspects of wider sociocognitive development. Quantitative genetic analyses provide additional information on similarities and differences between these domains at the level of etiology. That is, this study begins to address the relative contributions of genetic and environmental mechanisms that underlie the links between these behaviors.

The finding of a moderate phenotypic association between imitation and MDI indicates that, beyond simply providing an efficient means for acquiring new behaviors, imitation may serve as an important indicator of overall mental ability. This is supported by major theoretical constructs of cognitive development such as Bandura's (1989) Social Cognitive Theory, which proposes that observational learning cannot take place without the necessary cognitive capacities for attending to, processing, and remembering observed actions. Examining this association at the behavior genetic level reveals that the correlation between elicited imitation performance and MDI is to some extent explained by overlapping genetic and environmental influences.

Aside from a report of shared genetic influences on imitation and vocabulary development (McEwen et al, 2007), the present research is the first to directly examine genetic and environmental contributions to the observed association between imitation and mental ability, and is the first to do so via a standardized measure of mental development. Findings of substantial genetic and shared environmental overlap are therefore particularly revealing, demonstrating that many of the same etiological factors operate on both mental ability and imitative performance in the laboratory. This overlap between mental ability and imitation

may reflect pleiotropy (i.e., the same genes influencing multiple phenotypes), activity of common brain structures, or the fact that one capacity to some extent underlies the other.

Links between imitative performance and Task Orientation, a temperament dimension reflecting aspects of executive functioning including the abilities to stay on-task and focus attention on environmental stimuli, are also in line with Bandura's Social Cognitive model, which posits attention as the first in the series of cognitive processes necessary for successful learning via observation (Bandura, 1989). Because of the important role of attention in imitative learning, it stands to reason that this ability would serve as a predictor of successful imitation in the laboratory. The present research extends this theoretical construct at the level of etiology, demonstrating that the two capacities are at least partially reflective of the same underlying genetic mechanisms.

The phenotypic association between imitation and Affect/Extraversion indicates that children who were generally more positive and socially outgoing in the laboratory were more likely to imitate. Prior research has suggested similar links between imitative performance and extraversion-like traits in infants (Hilbrink et al, 2013) and young children (Fouts & Click, 1979), a finding extended in the present study to include a larger sample of toddlers and addressing the etiological mechanisms linking the two domains. Again, these findings may be viewed through the framework of the Social Cognitive model, which proposes that, in addition to attending to, remembering, and being capable of reproducing an observed behavior, a child must also be motivated to do so (Bandura, 1989). This motivation usually takes the form of expected reinforcement for imitating the modeled behavior – in this case, the expectation of a positive social interaction with the adult model.

Prior studies have shown that infants (Hanna & Meltzoff, 1993) and children (Roberts et al., 1981) often use imitation, whether consciously or unconsciously, with the goal of showing interest in and gaining favor or attention from others. Likewise, both teachers and peers have been shown to demonstrate a stronger affinity for highly imitative children (Thelen, Frautschi, Roberts, Kirkland & Dollinger, 1981), suggesting that the relation between imitation and extraversion may be a reflection of the naturally developing repertoire of social skills and behaviors in the extraverted child. In fact, findings of significant genetic influences on extraversion in prior research (e.g., Saudino, DeFries, & Plomin, 1995) as well as findings of significant genetic overlap across the domains of imitation and Affect/Extraversion in the present sample of toddlers further bolster this premise.

The genetic links between children's imitation, temperament and mental development arise due to the same genetic factors. That is, the genetic factors that link imitation to cognitive ability are the same as those that link imitation to temperament and to some extent the three domains tap the same genetic influences. At the same time, the presence of unique genetic variance on imitation suggests that imitation is not simply an index of overall mental development. In fact, approximately two-thirds of the genetic variance underlying elicited imitation was specific to imitation; in other words, considerable genetic influences underlie elicited imitation performance that are *independent* of those operating on MDI or temperament. This is a key consideration, as it demonstrates that imitation is not simply an epiphenomenon of mental development or temperament. Imitation shares some underlying

influences with mental ability and aspects of temperament, but is not merely a manifestation of general intellect or dispositional style.

In addition to genetic factors, shared environmental influences may serve to enhance similarity between family members for a particular behavior or trait. In the present research, all of the shared environmental effects found to operate on elicited imitation were the same as those influencing both temperament and mental development. Behavioral genetic studies consistently find evidence of shared environmental influences on individual differences in young children's cognitive development (e.g., Cherny, Fulker, Emde, Plomin, Corley & DeFries, 2001; Price, Eley, Dale, Stevenson, Saudino & Plomin, 2000; Hughes, Jaffe, Happe, Taylor, Caspi, & Moffitt, 2005), and these appear to drive the shared environmental connection with imitation and temperament in the present study. Research is needed to identify specific sources of shared environmental variance; however, socioeconomic status, parenting behaviors and even prenatal factors have been proposed as possible candidates (Price et al., 2000). Our findings indicate that the family-wide environments that influence mental development may also influence temperament and imitation, though to a lesser degree.

Taken together, the behavioral genetic evidence suggests that the underlying factors contributing to twins' similarity in imitative performance are to some extent the same as those contributing to similarity in mental performance and in social attentiveness and engagement. Though beyond the scope of the present research, future studies may further elucidate this relationship from a molecular genetic, and even epigenetic, perspective. For example, it is possible that the expression of the specific genes underlying these three domains are similarly influenced by certain environmental experiences such as patterns of reinforcement, attention, or opportunities to demonstrate learning. Differential exposure to such influences, which would impact the expression of associated genes to make individuals appear different from one another in imitative performance, is represented in the present research under the broad heading of nonshared environment.

Nonshared environmental factors are those that serve to make family members behaviorally different. Nonshared environmental influences on imitation were largely independent of those underlying mental development and temperament with the exception of modest nonshared environmental covariance with Task Orientation, indicating that some of the factors that make twins different in their imitative behavior covary with those that make the twins different in their observed attention and persistence. Situation-specific factors might explain this nonshared environmental association. For example, tester personality may be a source of differences between twins in that testers might be more or less engaging (e.g., Yu & Kushnir, 2014; Brugger, Lariviere, Mumme, & Bushnell, 2007; Nielsen, 2006), and may thereby engender greater or lesser attention to the imitation demonstration. Another possible explanation might lie in the timing of the tests. Because both the laboratory environment and tester would be somewhat more familiar on the second day of testing, it is possible that children might be more relaxed and attentive to the imitation paradigm on day 2. Conversely, children tested on the second day might feel more comfortable with the situation and therefore be less inclined to attend and more inclined to explore their environments. In either scenario, timing of test could influence the link between attention and imitative

performance, providing a unique contribution to the covariance across each child. However, despite the plausibility of these potential sources of overlapping nonshared environment, neither of these possible timing-related scenarios appears to have contributed to the covariance between elicited imitation and Task Orientation in the present sample, as comparisons between the first and second day of testing revealed no significant differences in either elicited imitation score or tester-rated Task Orientation within participants. Identifying specific sources of nonshared environmental variance and covariance thus remains to be explored in future research.

Three possible limitations to the current study should be acknowledged. First, because participants were pre-screened for possible developmental issues (for example, low birth weight, developmental disabilities), the results cannot be easily generalized to atypical populations. Nonetheless, most developmental research is conducted on samples that have similar characteristics and the methodology used to screen participants is typical of that used in most studies of typically developing children. Second, the measure of temperament used in the present analyses was completed by testers based on their observations of the children during two visits to the laboratory, rather than using a parent-report measure of temperament. We acknowledge that this may provide a somewhat limited view of the children's day-to-day behaviors; at the same time, in terms of elucidating temperamental similarities and differences between twins, particularly those related to their performance on laboratory tasks, tester-rated temperament may yield a more useful measure. Parents, particularly parents of twins, are known to exhibit contrast effects – that is, they exaggerate differences between their children when rating their temperament (e.g., Saudino, 1997; Saudino, Wertz, Gagne, & Chawla, 2004). For this reason, we felt that testers would provide more objective ratings of the twins in the laboratory situation. Moreover, because imitative tendencies were similarly inferred based on relatively brief laboratory observations of behavior, our subsequent analyses of genetic and environmental covariance based on these behavioral samples may be more informative.

Finally, we assessed imitation in the laboratory context only. Imitation within the lab may differ from imitation within the child's natural environments. However, laboratory studies are representative of the majority of the literature on imitation; therefore the present results inform on the phenotype in the environment in which it is typically studied, and from which inferences on children's cognitive development are typically made. Nonetheless, it would be informative to further analyze the phenomenon of young children's non-directed imitation using data gathered in other contexts.

The present findings indicate that toddlers' multi-step elicited imitation performance shares some underlying genetic influences with mental ability, as well as attentional and social aspects of temperament. However, findings of substantial independent genetic and nonshared environmental influences above and beyond those shared with mental performance and temperament indicate that imitation is not merely a reflection of these abilities. This finding is important as it emphasizes that elicited imitation has many underlying genetic and environmental influences that are unique. Thus, while mental ability, attention and extraversion may predict imitative performance to some extent, there appear to be other factors at work underlying the development of imitation in young children.

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Figure 1.
Distributions of individual components of composite imitation score.

Figure 2.
Distribution of composite elicited imitation scores.

Figure 3.

Cholesky model decomposing the genetic and environmental covariance between MDI, Task Orientation, Affect/Extraversion, and elicited imitation. The four rectangles represent the phenotypic variances of each variable. The circles represent latent additive genetic (A), shared environmental (C), and nonshared environmental (E) factors. The single-headed arrows extending from each of the A, C, and E factors represent partial regressions indicating the influence of the latent variable on the phenotype. The paths leading from MDI, Affect/Extraversion, and Task Orientation to elicited imitation represent genetic and environmental covariance between elicited imitation, mental development, and temperament, whereas the unique factors A1, C1, and E1 represent unique genetic or environmental influences on elicited imitation that are independent of temperament or mental development.

Figure 4.

Additive genetic, shared environmental, and nonshared environmental parameter estimates (and 95% confidence intervals) for the full quadrivariate Cholesky model. Significant parameter estimates are depicted in bold.

Figure 5.

Additive genetic, shared environmental, and nonshared environmental parameter estimates (and 95% confidence intervals) from the best-fitting quadrivariate Cholesky model.

Figure 6.
Relative contributions of genetic and environmental factors to the phenotypic correlations between variables.

Table 1

Inter-rater Reliability Means and (Standard Deviations) For Each Individual Dimension of Each Elicited Imitation Task.

Task/Dimension	Mean (Standard Deviation) Rater 1	Mean (Standard Deviation) Rater 2
Puppet/Removes Mitten	.61 (.49)	.63 (.49)
Puppet/Shakes Mitten	.38 (.49)	.37 (.49)
Puppet/Replaces Mitten	.41 (.50)	.51 (.50)
Puppet/Sequence	.16 (.37)	.21 (.41)
Puppet/Total (max 4 points)	1.58 (1.52)	1.50 (1.44)
Birdhouse/Pulls Pin	.98 (.14)	.98 (.14)
Birdhouse/Twists Pin	.51 (.51)	.55 (.50)
Birdhouse/Pulls Door	.86 (.35)	.87 (.34)
Birdhouse/Opens Door	.67 (.48)	.67 (.48)
Birdhouse/Removes Bird	.60 (.49)	.56 (.50)
Birdhouse/Vocal Imitation with Bird	.52 (.50)	.31 (.47)
Birdhouse/Gestural Imitation with Bird	.12 (.33)	.12 (.33)
Birdhouse/Sequence	.43 (.50)	.33 (.47)
Birdhouse/Total (max 8 points)	3.78 (2.36)	3.53 (2.27)
Rattle/Ball	.97 (.18)	.97 (.18)
Rattle/Handle	.90 (.31)	.90 (.31)
Rattle/Shake	.27 (.45)	.20 (.41)
Rattle/Sequence	.53 (.51)	.50 (.51)
Rattle/Total (max 4 points)	2.67 (.96)	2.57 (.90)

Table 2

Means and (standard deviations) for Elicited Imitation, MDI, and IBR Temperament Factors by Sex and Zygosity.

Measure	MZ Twins				DZ Twins				Sex x Zygosity <i>z</i> (<i>p</i>)		
	Males		Females		Males		Females				
	<i>M</i> (<i>SD</i>)		<i>M</i> (<i>SD</i>)		<i>M</i> (<i>SD</i>)		<i>M</i> (<i>SD</i>)				
Elicited Imitation	8.99 (3.40)		8.94 (3.13)		9.75 (3.15)		9.64 (3.10)		.82 (.41)	.03 (.98)	-.11 (.91)
MDI	86.74 (16.21)		88.36 (15.00)		93.09 (12.57)		95.10 (12.84)		1.23 (.22)	.26 (.80)	.13 (.89)
IBR Activity	.17 (.83)		.23 (.81)		-.20 (.77)		-.24 (.72)		1.01 (.31)	.71 (.48)	-.73 (.46)
IBR Affect/Extraversion	-.06 (.50)		-.07 (.48)		.04 (.46)		.11 (.40)		.08 (.94)	-.67 (.50)	1.03 (.31)
IBR Task Orientation	-.11 (.78)		-.13 (.76)		.09 (.75)		.18 (.61)		.36 (.72)	-.61 (.54)	.83 (.41)

Table 3

Phenotypic Correlations Between Elicited Imitation, MDI, and IBR Temperament Factors.

	Elicited Imitation
MDI	.39 **
IBR Activity	-.07
IBR Affect/Extraversion	.33 **
IBR Task Orientation	.39 **

*

 $p < .01$;

**

 $p < .001$

Table 4

Twin Intraclass Correlations (ICC) and Cross-Correlations of MDI and Temperament with Imitation.

	Intraclass Correlations		Cross-Correlations with Imitation	
	MZ	DZ	MZ	DZ
Imitation	.49 **	.11	--	--
MDI	.76 **	.52 **	.43 **	.28 **
Affect/Extraversion	.35 **	.12	.22 **	.17 *
Task Orientation	.49 **	.21 *	.29 **	.20 **

*
 $p < .01$;**
 $p < .001$

Table 5

Genetic and Environmental Variance Components (and 95% Confidence Intervals) from the Best-fitting (Reduced) Model.

	A	C	E
	(95% CI)	(95% CI)	(95% CI)
MDI	.43	.34	.23
	(.23, .66)	(.12, .52)	(.18, .30)
Task Orientation	.30	.15	.55
	(.06, .48)	(.01, .35)	(.45, .66)
Affect/Extraversion	.22	.12	.66
	(.04, .38)	(.10, .30)	(.56, .77)
Elicited Imitation	.30	.11	.59
	(.09, .46)	(.01, .27)	(.48, .72)

Table 6

Genetic and Environmental Correlations (and 95% Confidence Intervals) for the MDI, Task Orientation, Affect/Extraversion, and Elicited Imitation from the Reduced Model.

	Task Orientation			Affect/Extraversion			Elicited Imitation		
	r_g	r_c	r_e	r_g	r_c	r_e	r_g	r_c	r_e
MDI	.77 (.49, .97)	1.00 (1.00, 1.00)	.26 (.12, .40)	.73 (.38, .97)	1.00 (1.00, 1.00)	.28 (.15, .41)	.62 (.34, .90)	1.00 (1.00, 1.00)	.00 (.00, .00)
Task Orientation	---	---	---	1.00 (.95, 1.00)	1.00 (1.00, 1.00)	.47 (.38, .56)	.48 (.23, .73)	1.00 (1.00, 1.00)	.46 (.19, .72)
Affect/Extraversion	---	---	---	---	---	---	.46 (.19, .72)	1.00 (1.00, 1.00)	.09 (.05, .14)