Published in final edited form as:

Behav Genet. 2007 September ; 37(5): 639–647. doi:10.1007/s10519-007-9160-5.

Toddler see, toddler do? Genetic and environmental influences on laboratory-assessed elicited imitation

Susan K. Fenstermacher and Kimberly J. Saudino

Department of Psychology, Boston University, 64 Cummington Street, Boston, MA 02215, USA

Susan K. Fenstermacher: skf73@bu.edu

Abstract

The imitative performance of 311 pairs of 24-month old twins (143 MZ, 168 same-sex DZ) was assessed via three multi-step imitative sequences. Composite imitation score correlations suggested the presence of genetic influences on imitation, with MZ correlations significantly exceeding DZ correlations. Univariate model-fitting procedures supported this finding. Substantial broad heritability was found for imitative performance, with no evidence for shared environment. However, we are unable to say with certainty to what extent this heritability is represented by additive and nonadditive genetic variance. Estimates of heritability derived from both ACE and ADE model-fitting procedures accounted for approximately 50% of the total variance, with the remaining variance in imitative performance attributable to nonshared environmental factors.

Keywords

Elicited imitation; Toddlers; Cognitive development; Twins; Imitation

Introduction

Children's imitative behavior has been of great interest to developmental researchers for over a century. An examination of the literature dating as far back as the early 1900s finds imitation studied for its relationship to empathic behavior (Lipps 1906), while Piaget (1962) later cited children's capacity for imitation as one of the hallmarks of early developmental achievement. According to the Piagetian stage model of cognitive development, children's ability to recognize and subsequently reproduce the behavior of another was evidence of the attainment of certain cognitive processing skills not present at birth. However, recent findings of imitation in neonates calls into question the rigidity originally assumed for the emergence of this capacity in the later stages of early infant development. It has been demonstrated, for example, that newborns are able to imitate a wide range of gestures, including tongue protrusion, mouth opening (Meltzoff and Moore 1977), smiling and frowning (Field 1983), suggesting that imitation may reflect an innate behavioral propensity. Interestingly, even at birth, such behaviors evince substantial variability across infants (Heimann 2002). Despite such findings, however, very little scientific inquiry to date has

attempted to explore the underlying factors contributing to individual differences in children's capacity for imitation. This is particularly surprising given our current knowledge of imitation's prominent role across early development.

Normal development of imitative behavior

The capacity to learn and interact through imitation is of particular importance during early infancy and childhood. For example, there is evidence to suggest that 12 to 18 month-old infants may acquire one to two new behaviors per day through imitation (Barr and Hayne 2003), and even prior to the age that infants begin to comprehend verbal instruction, they may derive some skills and behavioral patterns through observation and subsequent mimicry of another's behavior (Meltzoff and Moore 1997). As such, the capacity for imitation serves as a valuable tool for learning about oneself and the people and objects one comes into contact with (Hanna and Meltzoff 1993). In fact, recent research suggests that imitation may actually be a more efficient mode of learning than mechanisms such as trial and error or even independent problem solving (Barr et al. 1996). While it is now apparent that human infants possess some rudimentary capacity for imitation at birth, imitative behavior nonetheless shows clear developmental progress throughout infancy and toddlerhood. Normally developing infants demonstrate some capacity to imitate gestures such as simple hand and facial movements within the first six months of life (Meltzoff 2002). Infants as young as a few hours old have been observed to attempt vocal imitation as well (Kugiumutzakis 1999), demonstrating a reliable capacity to imitate basic vowel sounds by 12 weeks of age (Kuhl and Meltzoff 1996). As children continue to develop along a normal cognitive trajectory, the complexity and specificity of their imitative potential increases correspondingly. Children between the ages of 6 and 24 months become increasingly proficient at imitating complex, multi-step motor sequences (Barr et al. 1996), as well as becoming more discriminatory with regard to the types of behaviors imitated. For example, by around 15 months of age, children begin to demonstrate the ability to discriminatively imitate what they perceive to be *intentional* actions, rather than simply imitating what they see (Meltzoff 1999). In other words, children at this age who observe a "failed attempt" at reaching a goal will imitate only those observed actions that allow them to successfully achieve the perceived goal of the model. Rather than faithfully imitate the "failure", children 15 months of age and older demonstrate an ability to infer the goals of the model, and to utilize that information by imitating only the necessary observed actions (Meltzoff 1995). Children show similar developmental progress with regard to their abilities to imitate multi-step sequences (Barr et al. 1996), with children at 24 months consistently exhibiting the most accurate imitative reproduction of multi-step actions compared to their younger counterparts. Because imitative ability develops to become fairly specialized in early toddlerhood, much imitation research is focused on children in this age range. Imitation paradigms of varying complexity are frequently used with toddlers to assess the normal development of significant features of cognitive functioning, including memory, learning, and the development of Theory of Mind, the recognition of others as mentally functioning individuals similar to oneself.

Individual differences in imitation

In addition to showing a clear developmental progression from infancy through toddlerhood, imitative behavior also evinces substantial individual differences. Such differences have been shown to remain stable over time. For example, children assessed longitudinally on a deferred imitation task at ages 9 and 14 months show both developmental increases in overall imitation (i.e., children at 14 months tended to imitate more behaviors in a multi-step sequence than they had at nine months) as well as stability of individual imitative tendencies (i.e., those children who were comparatively “low” imitators at 9 months remained so at 14 months, and vice versa) (Heimann and Meltzoff 1996). These findings suggest that imitative behavior shows unmistakable individual variability that appears to remain stable across development. Yet surprisingly, almost no scientific inquiry to date has attempted to explore the specific underlying factors contributing to individual differences in normally developing children’s capacity for imitation. *Why* do some children consistently imitate more than others? One possibility is that these observed behavioral differences may be influenced by genetic differences.

Studies examining imitation from a behavioral genetics perspective are scarce. The first published behavioral genetic investigation of imitation (Matheny 1975) included one vocal (says “da da”) and one gestural (pats doll) imitation item from the Bayley Mental Scale (Bayley 1969) included as part of a larger assessment of twins’ performance on Piagetian-type tasks at 3, 6, 9, and 12 months. Monozygotic twin concordances for performance on both of the imitation tasks significantly exceeded dizygotic twin concordances, suggesting the presence of genetic influences.

This finding represents the first to suggest genetic influences on imitative performance in children, and as such provides a major foundation for the present research. However, a number of important issues must be considered along with these results. First, and perhaps most importantly, this study examined only concordance rates for the imitative behaviors assessed; Heritability, or the genetic effect size, was not estimated. Likewise, Matheny’s (1975) use of a single pass/fail measure for the assessment of each aspect of imitation represents a very narrow, yet at the same time very gross measure of imitative behavior, in that each individual’s imitative performance in either of the two (vocal or gestural) domains is represented via the reproduction of a single behavior. Moreover, the all-or-nothing nature of the two pass-fail items might potentially bias findings toward shared environment by inflating both MZ and DZ twin resemblance. In other words, chance alone would predict concordance rates greater than zero if based on the pass/fail performance of a single-step measure. For these reasons, further behavioral genetic examination of imitation, using comprehensive multi-step measures and more sophisticated analytical procedures, would be required before making a confident statement regarding the heritability of this behavior.

Recently published behavioral genetic research (McEwen et al. 2007) using data from the Twins Early Development Study (TEDS) attempted to address this concern, utilizing sequential parent-administered gestural imitation tasks in its assessment of children’s imitative ability. Using model-fitting techniques, this study found moderate heritability for imitation (30%), though the greatest proportion of variance was accounted for by shared

environmental factors (42%). McEwen et al. acknowledge that this substantial shared environment may be attributed to rater bias on the part of parents, as all of the imitation tasks used in this study were parent-administered in the home (i.e., both twins were assessed by the same parent). This may be the case, but we suggest that there may be even another explanation for this pattern of results. Because the imitation tasks used in the aforementioned research included one or more explicit instructions to children to copy the behavior they had seen a parent execute (e.g., “Can you do that?” and “Do what I do”), it is possible that the results of this manipulation may not be an entirely pure reflection of genetic and environmental influences on children’s imitative performance *per se*. Rather, the explicit wording used to instruct children during these imitation tasks leads us to wonder whether the genetic and environmental factors proposed to operate on imitation in this case may be confounded with genetic and environmental influences on the behavioral dimension of compliance. Indeed, links between compliance and imitation, particularly when explicit instruction is given by a parent, have been previously demonstrated in the developmental literature (Forman and Kochanska 2001), and the substantial proportion of shared environment found for imitation in McEwen et al.’s paper is likewise remarkably similar to patterns of genetic and environmental influences found for compliance at age two (Saudino et al. 2007).

Obviously, further research is needed to more carefully examine the nature of influences underlying individual differences in imitation. The present study uses a behavioral genetic approach in an attempt to target children’s imitation at its most basic level, addressing the aforementioned possible confounds both by eliminating explicit instruction from the imitation paradigms (e.g., saying “It’s your turn to play” rather than “Do what I do” or “Can you do that?”), and by having the tasks carefully scripted and administered to each twin *separately* by different experimenters in a controlled laboratory setting. In addition, we employ three multi-step imitation paradigms that have been well-established in the developmental literature on imitative behavior. Though the paradigms used in the present research employ mostly gestural behaviors, some vocalizations are also included, thereby providing some information on the heritability of children’s vocal imitation beyond concordance rates (e.g., Matheny 1975). It is hoped that by reducing the explicit demands on the child for imitation and by eliminating a common tester as a source of covariance, we may more accurately be able to assess the relative contributions of genes and environment to a more pure assessment of children’s imitation at age 24 months.

Method

Sample

Three hundred and eleven same-sex (73 MZ male; 70 MZ female; 92 DZ male; 76 DZ female) 24 month-old twin pairs participated in this study. Participants were recruited via mail and telephone from the greater Boston area through the Boston University Twin Project. Prior to participation, all twins were preferentially screened so as to exclude any children who were not of normal birth weight or gestational age, or who presented with possible developmental issues (e.g., chromosomal abnormalities) that might affect their behavioral assessments or task performance. This method of participant screening represents

standard procedure used in most major developmental twin studies (i.e., the MacArthur Longitudinal Twin Study and the Twins Early Development Study) and ensures that results are not skewed by data which is not representative of the general population from which the sample was derived. Zygosity of the twins was assessed by DNA cheek swab analyses. In instances where the results of the DNA analyses were not available ($n = 3$ twin pairs), zygosity was determined using parent reports of twins' physical similarity and instances of identity confusion. Zygosity classification via parent reports has generally been found to be very reliable in correctly assessing zygosity when compared with the results of DNA screenings (Goldsmith and Campos 1990). In our study, the agreement, as indicated by Cohen's kappa, between zygosity assessed through DNA analyses and parent questionnaires was .94 ($p < 0.0001$). Moreover, 97% of twins identified via parent ratings were found to have been identified correctly when checked against DNA screening results.

Design and analyses

Univariate model-fitting analyses were used to examine the relative contributions of segregating genes and environment to individual differences in imitation. For the present analyses, we assessed the best fitting model by testing the parameters A (additive genetic effects), C (shared environmental effects), D (nonadditive genetic effects), and E (nonshared environmental effects). A univariate (ACE) model was first applied to twin variance/covariance matrices using Mx maximum-likelihood model-fitting procedures (Neale 1997). Using this model, estimates of additive genetic and shared and nonshared environmental variances and their 95% confidence intervals were estimated. We fit the full model (ACE) and three reduced models: (1) a model that included additive genetic effects and nonshared environmental effects (AE); (2) a model that included shared and nonshared environmental effects (CE); and (3) a model that included only nonshared environmental effects (E). To evaluate for the possibility of non-additive genetic effects, we also fit an ADE model (along with its corresponding reduced models) to the data.

Procedure

Twins completed two laboratory visits scheduled approximately 48 hours apart. On both visits, twins engaged in a variety of behavioral and cognitive assessments. The imitation episodes were administered on separate days for each twin and twins were assessed by different testers. Responses were scored online (in situ) by the administering experimenter. To determine the reliability of this scoring method, the target behaviors of a subsample ($n = 140$ children) were additionally coded from videotape by trained research assistants who had not previously worked with any of the children. Interrater reliability between the online and videotape coding for all three tasks was found to be high, ranging from 0.90 to 0.97. For this reason, we were able to do away with the video coding method, so that all responses reported and used in the following analyses were based solely upon the online coding results.

Measures

Three tasks were used to elicit imitative behavior. For each of these tasks, a multi-step activity sequence was modeled by an adult experimenter, immediately followed by a brief

response period wherein all imitation of the adult's behavior by the child was recorded by the experimenter.

Elicited imitation measure 1: Puppet task

Materials: One commercially available generic animal puppet with two felt mittens (one with a hidden small bell attached).

Procedure: Derived from Barr et al.'s (1996) studies of imitative ability in 6 to 24-month-old infants, the puppet task consisted of a three-step imitative sequence. The demonstration began with the child seated at a small table facing the examiner, who wore the puppet on his or her right hand. The examiner directed the child's attention by saying, "Look, (child's name)". Once it was established that the child was watching the demonstration, the examiner removed a felt mitten from the puppet's right hand, shook the mitten to ring the hidden bell, and replaced the mitten on the puppet's hand. This sequence was repeated two more times before the examiner briefly moved the puppet out of the child's view and replaced the mitten with an identical mitten without the bell. This switch, also derived from Barr et al. (1996), was included to prevent the child from attentionally fixating on the bell, which may have inhibited performance of the final step in the imitative sequence (replacing the mitten on the puppet's hand). After completing this replacement, the examiner placed the puppet on the table in front of the child and within his or her reach and invited the child to play with the puppet by saying, "Now it's your turn to play with the puppet." A 90-s response period followed.

Participants received one point for correctly performing each of the following three steps: removes mitten, shakes mitten, replaces mitten. Additional credit was received if the behaviors were performed in the sequence that they were modeled, so that the highest possible score on this task was four points.

Elicited imitation measure 2: Birdhouse task

Materials: Adapted from Carpenter et al. (2002), the birdhouse task apparatus consisted of a wooden birdhouse modified with a wooden pin that slid out of the left side to release the front door. The birdhouse also had a locking mechanism so that once the pin was slid out, a block of wood fell down to cover the opening, prohibiting reinsertion of the pin. A strip of blue tape ran along the bottom of the front door to clearly mark the point of opening. A small rubber toy bird was placed inside the birdhouse.

Procedure: The examiner placed the birdhouse on the table facing the child and directed the child's attention to it, saying, "Watch this". The examiner then visibly twisted the pin in an exaggerated turning motion, pulled the pin out of the side of the birdhouse, opened the door at the blue strip, and retrieved the toy bird. Following the retrieval of the toy bird, the examiner performed vocal and gestural actions designed to elicit imitation (i.e., said, "Look, it's a birdy! Cheep cheep cheep!" while performing a hopping motion with the toy). It should be noted that the twisting of the pin and vocal/gestural behaviors with the toy bird actually have no bearing on successfully removing the pin or retrieving the toy and are thus irrelevant to the achievement of target goals. The examiner then replaced the bird and pin

and presented the birdhouse to the child. The child was then given 60 s from first contact with the birdhouse in which to replicate the actions.

The following behaviors were assessed in scoring the birdhouse task: twists pin, pulls pin, pulls door, opens door, retrieves bird, and replicates vocal and gestural behaviors with bird. Participants received credit for each individual action that was performed correctly, as well as additional credit if the actions were performed in the correct sequence, so that the highest possible score on this task was eight points.

Elicited imitation measure 3: Rattle task

Materials: The rattle apparatus consisted of a clear plastic jar with an opening in the lid, a small rubber ball, and a handle that fastened to the top of the jar with Velcro®.

Procedure: The demonstration phase of this paradigm, adapted from Barr and Hayne (1999), began when the examiner placed three items (ball, jar, handle) on the table in front of the child. The examiner then performed the following sequence of events: placed the ball in the jar, attached the handle to the jar, and shook the completed rattle three times. The examiner then removed the handle and ball from the jar and repeated the sequence two more times, following the third demonstration by placing the individual pieces on the table in front of the child and inviting the child to play with the stimuli, saying, “Now it’s your turn to play.” A 60-s response interval began following the child’s first contact with the stimuli.

Participants received credit for each of the following behaviors performed accurately within the 60-second response period: puts ball in jar, attaches handle, and shakes rattle. Again, additional credit was given if the behaviors were performed in the correct sequence, so that the highest score for this task was four points.

Composite score

A composite elicited imitation score was derived by summing the total points received for each of the three multi-step elicited imitation sequences. The maximum possible composite imitation score was 16. This method of scoring yielded a reasonably normal distribution, as depicted in Figure 1.

Results

Descriptive statistics

Means and standard deviations for overall (composite) imitation scores by zygosity and sex are presented in Table 1. The mean composite imitation score was 9.30 (SD = 3.20). To account for dependence in the data due to the fact that our sample comprised pairs of twins, we evaluated the main effects of sex and zygosity and the sex x zygosity interaction on imitative behavior 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 and Zeger 1986; Zeger and Liang 1986). Neither the main effects of sex ($z = 0.82, p = 0.41$), zygosity ($z = 0.03, p = 0.98$), nor the sex x zygosity interaction ($z = -0.11, p = 0.91$) were significant. Most importantly, MZ and DZ

twin groups did not differ significantly in total variance on composite scores, thus fulfilling a basic assumption of the twin method.

Twin correlations

Twin correlations and their 95% confidence intervals were computed in a saturated model using Mx (model $-2LL = 3093.90$; $df = 598$). The MZ twin correlation, .49 (95% CI = 0.35, 0.61), was substantially larger than the DZ correlation, .12 (95% CI = -0.03 , 0.26). Moreover, the MZ correlation was significantly greater than the DZ correlation ($z = 5.18$, $p < 0.001$), suggesting the presence of genetic effects.

Model-fitting results

Table 2 presents fit statistics for the full model and alternative models, including parameter estimates and their 95% confidence intervals. The full (ACE) model adequately fit the data; however, the shared environment parameter (C) could be dropped from the model without a significant decrement in fit, suggesting that shared environment does not contribute significantly to the observed variability in imitative performance. This was not surprising given that C was estimated as zero in the full model. There were, however, significant additive genetic effects. The CE model (i.e., no genetic effects model) did not fit the data, as can be seen by the significant chi-square for the overall model. Not surprisingly, the model that included only nonshared environmental variance (E) provided the worst fit to the data. This makes sense, because the E-only model would imply that there is no resemblance between co-twins, which as can be seen from the twin correlations, is not the case for our sample.

Because the DZ correlation was less than one-half of the MZ correlation, it is possible that non-additive genetic effects might also contribute to the observed variance on our elicited imitation tasks. To determine whether and to what extent non-additive factors influenced our results, we next fit an ADE model (Table 2). The full ADE model actually provided a slightly better fit than the full ACE model, based on both χ^2 and AIC values. For this full ADE model, additive genetic effects were negligible, with the majority of variance explained by nonadditive genetic effects and nonshared environment. However, the 95% confidence intervals for both the A and D parameters included zero, suggesting that one of the genetic parameters could be dropped without a significant decrement in fit. Indeed, we found that dropping *either* the A or D parameter from the model provided a better overall fit to the data. The best-fitting model overall, based on AIC, was the ADE model. However, the difference in AIC between the AE and DE models was less than 2, suggesting substantial evidence for either model (Williams and Holahan 1994). Thus, it is not possible to distinguish between additive and non-additive genetic effects. Broad heritability (estimated at 0.48) derived from the full ADE model provides the best estimate of genetic influence, with the remaining variance in imitative performance attributable to nonshared environmental factors.

Discussion

Despite being traditionally examined in the context of group differences, studies of imitative behavior frequently reveal substantial individual variability. But *why* it is the case that some children consistently imitate more than others? Very few studies have attempted to directly answer this question. Our research indicates that individual differences in children's imitation are due, at least in part, to substantial genetic influences.

Taking a behavioral genetics approach to the study of imitative behavior represents an exciting new direction in the study of this relatively under-explored individual difference phenotype. The present finding of significant broad heritability for imitation lends strong support to evidence of genetic influences on imitation from the existing literature, while providing crucial additional information regarding the heritability of children's multi-step imitation that is both laboratory-administered and without explicit direction. Our use of well-established multi-step imitation measures culled from the contemporary cognitive development literature lends weight to these findings above and beyond that derived from the single-item and parent-directed tasks used to assess imitation in prior behavioral genetic research. Due to our relatively small sample size, however, we lack the power to resolve to what degree this genetic influence is due to additive and nonadditive genetic factors. At present, our results indicate substantial broad heritability, with hints of possible genetic dominance effects.

In addition to this considerable genetic contribution, nonshared environmental influences were found to contribute significantly to the observed variability in imitative performance. However, we found no evidence for any shared environmental contribution to imitation in our sample. In fact, a DE model proved the best fit to our data, further emphasizing this lack of shared environmental influence. This finding differs from a more recently published report of genetic and environmental influences on imitation (McEwen et al. 2007) that indicates substantial shared environment; in fact, the aforementioned research found shared environmental factors to account for the largest proportion of variance in imitation at age 24 months, a striking discrepancy from the results of our study. One explanation for this discrepancy, as suggested by McEwen et al., is the possibility of rater bias due to their exclusive use of parent-administered imitation tasks. Whenever twins are assessed by the same testers (i.e., the parent in the TEDS research), there is the possibility that rater effects are shared across twins, thereby inflating shared environmental influences. This is certainly a plausible explanation, as our imitation paradigms were separately administered to each twin by different testers, thereby eliminating an important source of covariance between twins. However, as suggested earlier in this paper, an alternate explanation may be found in our efforts to remove explicit compliance demands from the imitation paradigms used in the present study. In avoiding explicit instructional wording such as "Do what I do" or "Can you do that?" in our imitation scripts, it was our intention that children's perceptions of compliance expectations for these tasks would be kept at a minimum. With this in mind, if it is indeed the case that the shared environmental component observed in prior research is reflective of shared environmental influences on compliance rather than on imitation, we would expect to find a different pattern of results as a result of this manipulation. However, because our study controlled for *both* rater bias and compliance effects, we cannot say which

of these factors best explains the substantial shared environment found for imitation in the TEDS study. It may be a result of either factor, or perhaps even a combination of both. We propose, therefore, that the lack of shared environmental influences found for children's performance on our imitation measures may provide a more accurate reflection of the relative genetic and environmental contributions to children's imitative performance, with less possibility that these influences may be confounded with those on children's compliance behaviors or rater effects.

Though we found no evidence for shared environmental influences on imitation, our findings clearly demonstrate that *nonshared* environment exerts considerable influence on children's individual imitative propensities. This finding of substantial nonshared environmental influences on children's imitation raises questions as to what specific features of children's unique experiences might contribute to and shape their tendencies to imitate a model. Social learning theorists might speculate that children experience different reinforcement histories for their past imitative actions, thus contributing to individual differences in their learned tendencies to imitate. In addition, everyday experiences, including the salience of behaviors children might witness, how frequently they are exposed to particular observed behaviors or activities, and their relationships to potential models they might encounter, are all aspects of nonshared environment that may contribute to individual differences in children's imitation. Because of imitation's demonstrated usefulness as a learning tool, investigating specific sources of nonshared environmental impact on this behavior will provide valuable insight into what aspects of the environment might merit further attention, or perhaps even be manipulated as to better impact and maximize children's individual learning potentials.

The finding that genes clearly contribute to children's imitative tendencies has brought developmental researchers one important step closer to understanding the mechanisms underlying this complex phenotype. However, much remains to be learned, particularly with regard to what specific underlying phenotypes, if any, might be expressed via children's imitation of a model. What exactly *is* imitation? Does imitative capacity merit consideration as a trait unto itself, or is it rather reflecting some other genetically-influenced capacity, such as cognitive ability or memory? Elicited imitation paradigms have been and continue to be used in research tapping such features of normal cognitive development, and are generally found to be quite efficient means of getting at these abilities. Recent research (McEwen et al. 2007), in fact, has demonstrated a relationship between genetic factors operating on imitation and vocabulary, providing some support for the idea that cognitive factors may share some genetic and environmental influences with imitative performance. However, while there may be some common genetic influences on imitation and certain cognitive skills, this relationship would not imply an epiphenomenon of cognitive ability. Indeed, research incorporating measures of imitation and cognitive ability, for example, tend to find only moderate relationships between the two (DeBoer et al. 2005; Cheatham et al. 2006), suggesting that while these variables are associated with one another, the underlying capacities they represent are not one and the same.

In addition to the associations between imitative behavior and cognitive development, it is possible that certain aspects of temperament, such as sociability or shyness, may be tapped

by measures that require public performance of behaviors in a social context. Imitation is a behavior with demonstrated social significance (Fenstermacher and Saudino 2006), and contemporary research suggests that the social aspect of imitation may be so important to its execution as to inhibit performance of imitative actions in unfamiliar contexts or with unfamiliar testers (Learmonth et al. 2005). Such findings suggest that imitative performance in the laboratory may be influenced in part by children's temperament, and that perhaps genetic influences underlying imitation and temperament variables may overlap to some extent. Indeed, evidence suggesting some degree of overlap between genetic and environmental influences on social aspects of parent-rated temperament with those on elicited imitation has recently emerged in the literature (McEwen et al. 2007). At question is whether these relationships will continue to emerge when both imitation and temperament are tested more objectively, providing a basis for further exploration of the relationship between imitation, temperament, and social development.

Finally, we are curious as to the extent to which different *types* of imitation tasks tap the same set of skills or underlying abilities. Does "spontaneous" imitation—that which is not clearly elicited by a model with the implicit or explicit expectation that the behaviors will be reproduced—call upon the same underlying resources as the tasks described here? Does it merit consideration separate from elicited imitation, or are they merely different aspects of the same underlying capacity? We are currently testing a measure of spontaneous imitation in our sample and hope to use this data in future attempts to address the question of what, if any, specific facets of imitation set this ability apart from its related features of cognitive development. It is expected that this manipulation will yield important data that will allow us to make a more definitive assessment of what exactly is being measured with a particular type of imitation paradigm, and what such paradigms might tell us about this apparently pervasive aspect of children's early cognitive development.

In terms of generalizability, there are two possible limitations to our findings. First, because we pre-screened our participants for possible developmental issues (e.g., chromosomal abnormalities), we cannot say with certainty that these extreme populations are represented by our present results. Nonetheless, most developmental research is conducted on singleton samples that have similar characteristics to our own sample, and the methodology we used to screen participants is typical of that used in most studies of normally developing children. Additionally, while we acknowledge that it would be informative to further analyze the phenomenon of young children's non-directed elicited imitation using data gathered in other contexts, a second possible limitation may be that our project assessed imitation in the laboratory context only. However, this methodology is representative of the majority of the literature on imitation; therefore our work informs on the phenotype as it is typically studied, and from which inferences on children's behavior are made.

Despite some limitations, our finding of substantial broad heritability for multi-step imitative performance contributes exciting new information to the field of child development. Long understood as a group difference variable, and frequently examined from an exclusively environmental perspective, it was not until relatively recently that imitation was even recognized as a behavior with the potential for a wide spectrum of individual differences in its expression. That the propensity for this behavior might be

inherent, even present at birth, was a revelation brought forth and accepted only within the most recent decades. Our results thus support a more modern, comprehensive view of imitation as a substantially heritable propensity, for which expression may be mediated through one's unique environmental experiences. With strong implications for cognitive, personality, and social skill development, it is hoped and expected that future research examining the heritability of imitative behavior and its underlying components will continue to build and expand upon these findings.

Acknowledgments

This research was supported by grants MH062375 and F31 MH07662 from the National Institutes of Mental Health.

References

- Barr R, Dowden A, Hayne H. Developmental changes in deferred imitation by 6 to 24-month old infants. *Infant Behav Dev.* 1996; 19:159–170.
- Barr R, Hayne H. Developmental changes in imitation from television during infancy. *Child Dev.* 1999; 70:1067–1081. [PubMed: 10546335]
- Barr R, Hayne H. It's not what you know it's who you know: Older siblings facilitate imitation during infancy. *Int J Early Years Edu.* 2003; 11:7–21.
- Bayley, N. Bayley scales of infant development. The Psychological Corporation; New York, NY: 1969.
- Carpenter M, Call J, Tomasello M. Understanding “prior intentions” enables two-year olds to imitatively learn a complex task. *Child Dev.* 2002; 73:1431–1441. [PubMed: 12361310]
- Cheatham CL, Bauer PJ, Georgieff MK. Predicting individual differences in recall by infants born preterm and full term. *Infancy.* 2006; 10:17–42.
- DeBoer T, Wewerka S, Bauer PJ, Georgieff MK, Nelson CA. Explicit memory performance in infants of diabetic mothers at 1 year of age. *Dev Med Child Neurol.* 2005; 47:525–531. [PubMed: 16108452]
- Fenstermacher SK, Saudino KJ. Understanding individual differences in young children's imitative behavior. *Dev Rev.* 2006; 26:346–364.
- Field TM. Discrimination and imitation of facial expressions by term and preterm neonates. *Infant Behav Dev.* 1983; 6:485–489.
- Forman DR, Kochanska G. Viewing imitation as child responsiveness: a link between teaching and discipline domains of socialization. *Child Dev.* 2001; 37:198–206.
- Goldsmith HH, Campos JJ. The structure of temperamental fear and pleasure in infants: A psychometric perspective. *Child Dev.* 1990; 61:1944–1964. [PubMed: 2083507]
- Hanna E, Meltzoff AN. Peer imitation by toddlers, in laboratory, home, and day-care contexts: Implications for social learning and memory. *Dev Psychol.* 1993; 29:701–716.
- Heimann, M. Notes on individual differences and the assumed elusiveness of neonatal imitation. In: Meltzoff, AN.; Prinz, W., editors. *Imitative mind: development, evolution, and brain bases.* Cambridge University Press; New York: 2002. p. 74-84.
- Heimann M, Meltzoff AN. Deferred imitation in 9- and 14-month old infants: A longitudinal study of a Swedish sample. *Brit J Dev Psychol.* 1996; 14:55–64.
- Kugiumutzakis, G. Genesis and development of early infant mimesis to facial and vocal models. In: Nadel, J.; Butterworth, G., editors. *Imitation in infancy.* Cambridge studies in cognitive perceptual development. Cambridge University Press; New York: 1999. p. 36-59.
- Kuhl PK, Meltzoff AN. Infant vocalizations in response to speech: Vocal imitation and developmental change. *J Acoust Soc Am.* 1996; 100:2425–2438. [PubMed: 8865648]
- Learmonth AE, Lamberth R, Rovee-Collier C. The social context of imitation in infancy. *J Exper Child Psychol.* 2005; 91:297–314. [PubMed: 16042966]

- Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika*. 1986; 73:13–22.
- Lipps, T. *Leitfaeden der psychologie* [The principles of psychology]. Verlag von Wilhelm Engelmann; Leipzig, Germany: 1906.
- Matheny AP. Twins: Concordance for Piagetian-equivalent items from the Bayley Mental Test. *Dev Psychol*. 1975; 11:224–227.
- McEwen F, Happe F, Bolton P, Rijdsdijk F, Ronald A, Dworkynski K, Plomin R. Origins of individual differences in imitation: Links with language, pretend play, and socially insightful behavior in two-year old twins. *Child Dev*. 2007; 78:474–492. [PubMed: 17381785]
- Meltzoff AN. Understanding the intentions of others: Reenactment of intended acts by 18-month old children. *Dev Psychol*. 1995; 31:838–850.
- Meltzoff AN. Origins of theory of mind, cognition, and communication. *J Commun Disord*. 1999; 32:251–269. [PubMed: 10466097]
- Meltzoff, AN. Elements of a developmental theory of imitation. In: Meltzoff, AN.; Prinz, W., editors. *The imitative mind: development, evolution, and brain bases*. Cambridge University Press; New York: 2002. p. 19-41.
- Meltzoff AN, Moore MK. Imitation of facial and manual gestures by human neonates. *Science*. 1977; 198:75–78. [PubMed: 17741897]
- Meltzoff AN, Moore MK. Explaining facial imitation: A theoretical model. *Early Dev Parenting*. 1997; 6:179–192.
- Neale, MC. *Mx: Statistical modeling*. 3. Virginia Commonwealth University; Richmond, VA: 1997.
- Piaget, J. *Play, dreams, and imitation in childhood*. W.W. Norton and Company; New York: 1962.
- Saudino KJ, Carter AS, Purper-Ouakil D, Gorwood P. The etiology of behavioral problems and competencies in very young twins. 2007 Manuscript submitted for publication.
- Williams LJ, Holahan PJ. Parsimony based fit indices for multiple fit indicator models: do they work? *Struct Equation Model*. 1994; 1:161–198.
- Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics*. 1986; 42:121–130. [PubMed: 3719049]

Fig. 1.
Distribution of composite imitation scores

Table 1

Means and (standard deviations) for imitative performance by sex and zygosity

	MZ	DZ
Males	8.99 (3.40)	8.94 (3.13)
n_{pairs}	72	89
Females	9.75 (3.15)	9.64 (3.10)
n_{pairs}	68	76

Table 2

Model-fitting results

	A (95% CI)	C (95% CI)	D (95% CI)	E (95% CI)	Model χ^2	df	p	AIC	χ^2_a	df ^b	p
ACE	0.45 (0.23, 0.56)	0.00 (0.00, 0.16)	—	.55 (0.44, 0.68)	4.36	3	0.22	-1.64	—	—	—
ADE	.02 (0.00, 0.53)	—	0.46 (0.00, 0.58)	0.52 (0.42, 0.65)	2.49	3	0.48	-3.51	—	—	—
AE	0.45 (0.32, 0.56)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.55 (0.44, 0.68)	4.36	4	0.36	-3.64	0.00	1	—
CE	0.00 (0.00, 0.00)	0.30 (0.19, 0.40)	—	0.70 (0.60, 0.81)	14.88	4	0.01	6.88	10.52	1	.00
DE	0.00 (0.00, 0.00)	—	0.48 (0.35, 0.58)	0.52 (0.42, 0.65)	2.49	4	0.65	-5.51	0.00	1	—
E	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	1.00 (1.00, 1.00)	43.18	5	0.00	33.18	40.69	2	.00

A = additive genetic parameter; C = shared environmental parameter; D = nonadditive genetic parameter; E = nonshared environmental parameter; AIC = Akaike's Information Criterion. Lower AIC value denotes a better-fitting model.

^a Difference in chi-square between the full model and reduced models.

^b Difference in degrees of freedom comparing the full model and reduced model