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Parenting and Child Behaviour Problems: a Longitudinal Analysis of Non-Shared Environment

Paula Y. Mullineaux[a,*], **Kirby Deater-Deckard**[a], **Stephen A. Petrill**[b], and **Lee A. Thompson**[c]

a *Department of Psychology, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA*

b *Department of Human Development and Family Science, Ohio State University, Columbus, OH, USA*

c *Department of Psychology, Case Western Reserve University, Cleveland, OH, USA*

Abstract

This study examined potential non-shared environmental processes in middle childhood by estimating statistical associations between monozygotic (MZ) twin differences in externalizing and internalizing problems and positive social engagement, and differential maternal positivity and negativity, over 1 year. Seventy-seven pairs of identical twins participated (*M* = 6.08-years old, 65% male) in two annual home visits. Observers' ratings and maternal reports were gathered. At both assessments, the twin who showed more conduct problems (maternal report and observers' ratings) and less positive social engagement (positive affect, responsiveness) received more maternal negativity and less maternal warmth (self-reports and observers' ratings), relative to his or her genetically identical co-twin. The same patterns held over time, for the associations between change in differential MZ twin conduct problems and social engagement and change in differential maternal behaviour. Effects for child internalizing problems were not consistent within or across raters. Overall, these results indicated that differential maternal warmth and negativity—self-perceived and observed by others— are important aspects of sibling differentiation for both problematic and adaptive behaviours during middle childhood.

Keywords

non-shared environment; MZ twin differences; differential parenting; externalizing; parent-child relationship

INTRODUCTION

One of the most important findings emerging from developmental behavioural genetics research is the ubiquitous importance of non-shared environment on individual differences in behaviour. When individual phenotypic differences are not attributable to genetic differences among individuals, non-shared environmental influences are implicated. According to the behavioural genetic quasi-experimental design, non-shared environment represents those environmental influences that lead to sibling dissimilarity. Modest to moderate non-shared environment effects have been found for nearly every psychological and behavioural attribute that has been studied (Plomin & Daniels, 1987). Although genetically informative studies indicate the presence of non-shared environmental influences, for the most part the specific sources of these non-shared environmental effects have not been identified. In the current study,

*Correspondence to: Paula Y. Mullineaux, Department of Psychology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, USA. E-mail: E-mail: pmullin@vt.edu.

we used a 1-year longitudinal twin design to examine whether differential maternal warmth and negativity operate as potential non-shared environmental influences on child maladjustment, by studying differences within identical twin pairs (i.e. monozygotic or MZ) over 1 year during the transition to middle childhood.

Family Studies

Family studies focusing on between-family differences in parenting and child outcomes indicate that maternal negativity during parent–child interactions in early childhood is significantly related to multiple informants' (e.g. mother, teacher, child) ratings of child externalizing problems across the early school years (Denham *et al*., 2000; Heller & Baker, 2000; Park *et al*., 2005). Additionally, links between within-family processes and child negative outcomes also have been indicated. Within-family variation such as parental differential treatment of siblings has been linked to child behavioural problems (Conger & Conger, 1994; McGuire, Dunn, & Plomin, 1995; Stocker, 1995). Differential parenting appears to have the strongest impact on child adjustment for those children experiencing lower parental warmth and greater parental negativity (Feinberg & Hetherington, 2001).

In family studies, genetic and environmental influences are confounded, and it is unclear whether the relationship between parenting behaviour and child adjustment are due to 'child-general' parenting processes, which could lead to sibling similarity, or 'child-specific' parenting processes, which could lead to sibling dissimilarity (or operate through both mechanisms). Behavioural genetic studies can address this confound, by identifying shared environmental influences (i.e. non-genetic influences that lead to sibling similarity) and non-shared environmental influences (i.e. non-genetic influences that account for sibling dissimilarity). Shared environmental factors have been identified for a variety of child outcomes. For instance, recent studies have shown shared environmental influences in the link between parenting quality and infant attachment security (Roisman & Fraley, 2008), in conduct disorder and peer deviance (Kendler, Jacobson, Myer, & Eaves, 2008), and in externalizing behaviour problems in early childhood (Saudino, Carter, Purper-Ouakil, & Gorwood, 2008).

Nevertheless, children in the same family also differ on many characteristics, for which genetic influences have been implicated (e.g. temperament, cognitive abilities). These differences in genetic propensities may evoke different parenting experiences for siblings (i.e. child-specific parenting)—an example of evocative genotype–environment correlation (Scarr & McCartney, 1983). However, siblings differ not only because of differences in genotypes, but as a result of differences in environmental influences—referred to as non-shared environmental influences (which also includes measurement error). Through non-shared environmental mechanisms, child-specific parenting practices within each family might serve to further differentiate siblings, above and beyond any genetically influenced differences in the children's attributes. Although shared environmental influences are important, the identification of non-shared environmental mechanisms also is critical, given that most of the non-genetic variance in child cognitive and behavioural outcomes (and complex behaviours generally) is non-shared across siblings (Plomin & Daniels, 1987).

Non-Shared Environment

Siblings who are reared in the same home can be remarkably different from one another. With respect to child maladjustment, typical levels of biological full-sibling similarity for externalizing (i.e. aggression, delinquency) and internalizing (i.e. anxiety, depression) problems is *intra-class r* = 0.2–0.3 (Fagan & Najman, 2003). Thus, there are considerable differences between siblings for these behavioural and emotional problems. These sibling differences stem from differences in genotypes (given that full siblings share, on average, 50%

of alleles identical by descent) as well as differences in non-genetic environmental or experiential influences.

Because siblings living in the same home share some but not all of the potential genetic and environmental factors that influence their behaviours, teasing apart the potential influences of genetic and non-genetic factors that differentiate siblings is very difficult. Turkheimer and Waldron (2000) have noted that non-shared environmental influences—which include all of the random measurement error—may not be systematic, but instead may operate idiosyncratically and in ways that cannot be ascertained. Thus, the question is whether or not quasi-experimental behavioural genetic designs can be used to actually identify systematic non-shared environmental mechanisms cross sectionally and longitudinally. This is the impetus for the current study.

The most powerful and direct approach for identifying non-shared environmental influences is to examine identical (MZ) twin differences in behaviour. Although MZ twins are generally found to be more similar to each other in their social–emotional and cognitive developmental outcomes compared with fraternal twins and non-twin siblings, MZ twins still can differ markedly from each other with respect to their behavioural and emotional adjustment and problems. Since behavioural differences between MZ twins cannot arise from differences in genes, age, or sex, MZ twin differences provide the most direct estimate of the magnitude of non-shared environmental influences for any given attribute. These influences are referred to as non-shared, because they appear to result in sibling dissimilarity rather than sibling similarity —even when the siblings are reared together (Plomin & Daniels, 1987; Rowe & Plomin, 1981). Examples of potential non-shared environmental influences include sibling differences in accidents, illnesses, peer groups, hobbies and other extracurricular activities, and differential parental treatment (Dunn & Plomin, 1990). Thus, by examining MZ twin differences, non-shared environmental influences can be assessed directly because genetic influences on sibling differentiation are essentially held constant (Pike, Reiss, Hetherington, & Plomin, 1996).

The ‘MZ differences’ method cannot address causality. Differential parenting behaviour may be an outcome of differential child behaviour or alternatively, differential child behaviour may be an outcome of differential parenting behaviour. Another possibility is that the association between parenting and child behaviour is bi-directional in nature, whereby it is not possible to differentiate causal parent or child effects. However, given the importance of identifying non-shared and shared environmental influences in development, it is important to pursue the identification of some ‘candidate’ non-shared environmental processes using correlational and quasi-experimental designs—and in particular, candidate processes that involve individual differences within families over time. To this end, Asbury and colleagues published several papers examining potential sources of non-shared environment in early and middle childhood. They found a relationship between parent-reported differential harsh discipline and negativity and twin differences in problematic and prosocial behaviour at 4 years (Asbury, Dunn, Pike, & Plomin, 2003). In a follow-up paper, differential parenting at age 4 was associated with twin differences in teacher-reported behavioural problems and academic achievement 3 years later (Asbury, Dunn, & Plomin, 2006a). For twin differences in anxiety at 7 years of age, other potential sources of non-shared environmental influence were identified, including twin differences in school and peer experiences, illnesses and accidents, and traumatic neonatal life events (Asbury, Dunn, & Plomin, 2006b). Differential maternal behaviour at 5 years of age also has been associated with MZ twin differences in conduct problems at 7 years of age (Caspi *et al*., 2004).

Other studies of MZ twin differences have examined adolescent sibling differences in negative and positive life events, parent–child conflict and closeness, and friends’ and peers’ attitudes and behaviours. Burt and colleagues found associations between differential parent–adolescent

conflict at 11 years of age and twin differences in conduct problems at 14 years (Burt, McGue, Iacono, & Krueger, 2006). Liang and Eley (2005) reported associations between adolescent identical twins differences in self-reported depressive symptoms and self-reported differential experiences with respect to punitive parenting, negative life events, and peer behaviours. Crosnoe and Elder (2002) showed that within identical twin pairs, the twin who reported greater closeness to her mother and teacher or stronger religious group affiliation also reported lower levels of emotional distress.

Observing Change

Although there are a number of studies that have examined MZ twin differences to identify candidate non-shared environmental processes, only a few have utilized observational as well as questionnaire methods. Furthermore, to our knowledge, none has tested whether *changes over time* in differential parenting are associated with *changes over time* in identical twins' differences in behavioural adjustment. This raises the question whether these apparent non-shared environmental processes are readily observed by anyone (as opposed to being limited to knowledgeable informants' reports), or whether these processes operate over time as well as at any given point in time.

The Non-Shared Environment and Adolescent Development (NEAD) study (Reiss, Neiderhiser, Hetherington, & Plomin, 2000) was noteworthy because observer, self-report, and parent ratings were all used. Using multiple methods and informants, the NEAD study demonstrated that differential parenting and identical twin differences in problem behaviours were associated, suggesting that the detection of these effects was not limited to knowledgeable informants' questionnaire ratings (Pike *et al*., 1996). Subsequently, a smaller study of 3.5-year-old MZ twins that was modelled from the NEAD assessment protocol yielded a similar pattern of results (Deater-Deckard *et al*., 2001). In that study, hypothesized associations between differential maternal negativity and positivity were found with identical twin differences in negative affect, non-compliance, activity level, off-task behaviour, and responsiveness.

Thus, there have been several studies that have examined potential non-shared environmental processes over time or that have utilized observational as well as questionnaire methods, but to our knowledge the current study is the first to identify non-shared environmental processes involving *increasing or decreasing sibling differentiation over time*. The examination of change is a critical next step in this literature. Although ample evidence exists to support the importance of non-shared environmental variance, and a number of studies have begun to identify some of the potentially important non-shared environment processes that may account for this variance, the longitudinal nature of these candidate non-shared environment processes has never been tested directly. Therefore, our main goal was to see whether changes over 1 year in identical twins' differences in behavioural and emotional problems would be associated with changes over 1 year in maternal differential negativity and warmth. Based on the literature, we hypothesized that within the MZ identical twin pair, the child who showed a larger increase in problem behaviour over a 1-year period would also experience a larger increase in maternal negativity and decrease in maternal positivity, relative to her genetically identical co-twin. We also anticipated that the longitudinal non-shared environmental mechanisms that we identified would replicate within each cross-sectional assessment—thus, the associations between differential maternal behaviour and MZ twin differences in adjustment would replicate within and across time points. Finally, we examined the degree to which the statistical evidence for these cross-sectional and longitudinal non-shared environmental processes would be robust across informant/method.

METHOD

Participants

Data for 77 MZ twin pairs (65% male) from an ongoing, longitudinal study were utilized in this project. The children were assessed across two separate occasions 1 year apart. At the first assessment, the average age of the twins was 6.08 years, with a range of 4.33–7.92 years. There was a wide range of parental education that was similar for mothers and fathers: 1–2% high school or less, 39% some college, 30% bachelor's degree, and 25% some post-graduate education or degree, with 5% not reporting. The majority was two-parent households (94%) and Caucasian (92%).

Procedures

The primary caregiver (the mother in all but 6 of the 77 MZ twin pairs) was paired with each twin separately for participation in two 10-min video-taped cooperative tasks completed in the twins' homes. Because nearly all of the dyads were mother–child pairs, we refer throughout this paper to 'maternal' behaviour. These structured tasks consisted of an Etch-A-Sketch drawing toy (drawing a house together) and the navigation of a marble through a tilting wooden maze. The parent and child were instructed to only use their assigned control knob for each of the tasks, therefore requiring cooperation between the dyad. These video-taped sessions were later rated by trained coders using the Parent–Child Interaction System (PARCHISY; Deater-Deckard, Pylas, & Petrill, 1997). The PARCHISY is a global behavioural rating system that has been used widely to examine naturalistic behaviours in a variety of populations (Brophy & Dunn, 2002; Corapci, Radan, & Lozoff, 2006; Hughes & Ensor, 2005; Marks *et al*., 2006). Each parent–twin dyad was rated by a different coder at each wave to avoid potential rater bias on our estimates of twin similarity. Just prior to or following the home visit, each mother completed questionnaires regarding each child's problem behaviours and her feelings about each twin.

Measures

In order to assess positive and negative mother and child behaviour during both cooperative tasks, the PARCHISY was used. Different observers rated mother and child behaviour on 7-point Likert-type scales (1 = no occurrence of the behaviour to 7 = continual occurrence of the behaviour). Scores were averaged across the two cooperation tasks. All coders achieved Cronbach's $\alpha > 0.75$ during training and this level of reliability was maintained throughout data collection.

Observer ratings—Global ratings of mother and child behaviours were completed for each of the two cooperative tasks. Mothers' behaviours were rated for positive control (e.g. use of praise, explanation, open-ended questions) and negative control (e.g. use of criticism, physical control of the dials, physical control of the child's hand/arm/body) as well as mother positivity (e.g. positive affect—smiling, laughing) and negativity (e.g. negative affect—rejection, frowning, cold/harsh tone) during each of the cooperative tasks. In addition, mother responsiveness to the child's questions, comments, and behaviours during the tasks were rated.

Children's behaviour rated during the two cooperative tasks consisted of child positivity (e.g. positive affect—smiling, laughing) and negativity (e.g. negative affect—rejection, frowning, cold/harsh tone) during the tasks as well as how responsive the child was to the mothers' questions, comments, and behaviours. The degree to which the child stayed on task and the degree of non-compliance to maternal verbalizations during the interaction tasks were also rated. Additionally, children's level of autonomy (e.g. leading and controlling the tasks) was rated during the video-taped interactions.

We computed two composite scores representing observed maternal behaviour and two composite scores representing observed child behaviour. The first mother composite score represented observed *maternal positivity* (positive control, affect, and responsiveness). Principal components analysis (PCA) showed good internal consistency in the first assessment (53% of the variance accounted for, loadings from 0.70 to 0.77) and second assessment (65% of the variance accounted for, loadings from 0.76 to 0.84). The second mother composite score represented *maternal negativity* (negative control and affect); these two items were substantially correlated (first assessment, $r = 0.59$, $p<0.001$; second assessment, $r = 0.70$, $p<0.001$) so they were averaged to yield an observed maternal negativity score.

The first child composite score represented *negative behaviour* (negative affect, non-compliance, on-task [reverse scored]), with PCA indicating good internal consistency for the first (59% of the variance accounted for, loadings from 0.65 to 0.83) and second (60% of the variance accounted for, loadings from 0.74 to 0.82) assessments. The second child composite was *positive engagement* (positive affect, responsiveness, autonomy), with PCA again indicating acceptable internal consistency (first assessment, 43% of the variance accounted for and loadings from 0.64 to 0.68; second assessment, 50% of the variance accounted for and loadings from 0.61 to 0.76).

Mother ratings—Two validated and reliable questionnaires were completed by the mothers at each assessment. Mothers completed the 31-item Parent Feelings Questionnaire (Deater-Deckard, 1996) that consists of a 16-item Negativity scale and a 15-item Positivity scale. Mothers also completed the Child Behaviour Checklist (Achenbach, 1991) that yields two syndrome scores: Externalizing (aggressive and non-aggressive conduct problems) and Internalizing (anxiety/depression, withdrawal, somatic problems). These questionnaires were completed separately for each twin.

RESULTS

Descriptive statistics are presented in Table 1. Examination of mean levels at each assessment indicated a significant decrease over time in observed child negative behaviour for twin 1 ($t(77) = 2.64$, $p = 0.01$) but not for twin 2 ($t(77) = 1.45$, $p = 0.15$), and an increase over time in observed child positive engagement for twin 1 ($t(77) = -4.73$, $p = 0.001$) and twin 2 ($t(77) = -4.47$, $p = 0.001$). There was also a significant increase from wave 1 to wave 2 in observed maternal positivity for both twins 1 ($t(77) = -3.86$, $p = 0.001$) and twin 2 ($t(77) = -4.17$, $p = 0.001$). Significant mean level differences were not observed from wave 1 to wave 2 for maternal negativity for either twin 1 ($t(77) = 0.59$, $p = 0.56$) or twin 2 ($t(77) = -1.19$, $p = 0.24$). Likewise, there was no evidence of significant mean differences across the assessments for self-rated maternal positivity for twin 1 ($t(77) = 1.01$, $p = 0.32$) or twin 2 ($t(77) = 1.93$, $p = 0.06$). However, a significant decrease in self-reported maternal negativity was observed for twin 1 ($t(77) = -2.48$, $p = 0.02$) but not for twin 2 ($t(77) = -1.35$, $p = 0.18$). No significant differences were indicated across the assessments for mother-rated externalizing problems (twin 1: $t(77) = 1.15$, $p = 0.25$; twin 2: $t(77) = 0.66$, $p = 0.51$) or for mother-rated internalizing problems (twin 1: $t(77) = 0.24$, $p = 0.81$; twin 2: $t(77) = 1.05$, $p = 0.30$).

One-year stability was substantial for mothers' self-reported negativity ($r = 0.68$, correlations averaged across twins and significant at $p<0.05$ unless otherwise noted) and positivity ($r = 0.80$), as well as mothers' ratings of child externalizing ($r = 0.81$) and internalizing problems ($r = 0.64$). Moderate stability was found for observers' ratings of child negative behaviour ($r = 0.34$) and maternal positivity ($r = 0.27$). Observers' ratings of child positive engagement ($r = 0.13$, n.s.) and maternal negativity ($r = 0.16$, n.s.) were only modestly stable over 1 year.

Next, we estimated the associations between MZ twin differences in the measured environmental factor (e.g. maternal positivity) and differences in twin behaviour (e.g. positive engagement). First, birth order assignment (twin 1 or twin 2) was randomized for the sample. Then, we computed relative difference scores by subtracting the second-born twin's score from the first-born twin's score for all mother- and observer-rated behaviours (e.g. twin 1 positive engagement–twin 2 positive engagement) for each of the annual assessments (waves 1 and 2). This resulted in a twin difference score for waves 1 and 2 for each of the mother- and observer-rated behaviours (e.g. wave 1 positive engagement difference score, wave 2 positive engagement difference score). In order to determine whether changes in maternal and twin behaviour were systematically associated over time, we then computed relative change scores by subtracting the relative difference score at the second assessment from the relative difference score at the first assessment (e.g. wave 1 positive engagement difference score–wave 2 positive engagement difference score), which resulted in a change score for each of the mother- and observer-rated behaviours.

Our hypothesis was that the child who showed a larger increase in problem behaviours over a 1-year period also would experience a larger increase in maternal negativity and decrease in maternal positivity, relative to her genetically identical sibling. To test this, we examined the relative difference scores and the change in relative difference scores within informant (observer, mother) and across informant (e.g. observer-rated child negativity and mother-rated child externalizing behaviour). In our interpretation, we focused on significant effects that replicated across both assessments and in the analysis of change over time.

Within Informant

The within-informant results are presented in Table 2. First, we estimated the correlations between relative difference scores for observers' ratings (shown in the top half of Table 2). Consistent with our hypothesis, a modest but significant correlation (0.20 range) was found between differential maternal negativity and twin differences in negative behaviour at each assessment. In addition, a moderate significant association (0.40–0.50 range) was found between maternal differential positivity and twin differences in positive engagement at each assessment. Thus, at both time points, the child who was showing more negative behaviour and less positive engagement during the interactions also experienced more maternal negativity and less maternal positivity, respectively, compared with her identical co-twin.

The same pattern was found over time in analyses of change scores (also in Table 2). As hypothesized, change in observed differential maternal negativity was positively associated with change in observed twin differences in child negative behaviour, and change in observed differential maternal positivity was positively associated with change in observed twin differences in positive engagement. Thus, associations between differential maternal behaviour and twin differences in negative behaviour and positive engagement were evident over a 1-year period as well as at each time point.

Next, we estimated correlations within mothers' ratings; these are shown in the bottom half of Table 2. Consistent with our hypothesis, a modest but significant correlation (0.20 range) was found between mothers' self-reported differential negativity/positivity and their ratings of twin differences in externalizing problems. However, this was not the case for mothers' self-reported differential negativity/positivity and their ratings of twin differences in internalizing problems. At each assessment, mothers reported feeling more negative and less positive feelings towards the child; they also reported as displaying more externalizing behaviors.

A similar pattern was evident in the analyses of change scores of mothers' ratings (also in Table 2). As anticipated, change in mothers' self-reported differential negativity was positively associated with change in mother-reported child externalizing behaviour, and change in

mothers' self-reported differential positivity was negatively associated with change in mother-reported child externalizing behaviour. Therefore, there was evidence of the anticipated associations over time in the analysis of change scores for externalizing behaviour; the twin who was perceived as showing a greater increase in externalizing problems was also regarded with increasing negativity and decreasing positivity, relative to her co-twin.

Between Informants

Next, we estimated correlations between informants (mothers and observers; see Table 3). In the top half of Table 3, the correlations for mothers' ratings of differential parenting and observers' ratings of twin differences in behaviour are shown. However, there was no evidence of the hypothesized associations within each time point, none of these anticipated effects replicated across both time points and in the analyses of change. The same was true for observer-rated differential parenting and mother-rated twin differences in behaviour (bottom half of Table 3). There was one significant correlation, which was in the expected direction, but it was not replicated across both time points and in the analysis of change.

DISCUSSION

From childhood into adulthood, non-shared environmental processes account for most of the non-genetic variance in individual differences in complex human behaviour (Plomin, DeFries, Craig, & McGuffin, 2003). However, there have been few attempts to use multiple informants and methods to identify variables that operate through non-shared environmental mechanisms, and fewer still that have done so while also testing for change in behaviour over time. The goal of the current study was to conduct cross-sectional and longitudinal analyses of differential maternal negativity and positivity and identical twin differences in behavioural/emotional problems and positive engagement, in an effort to identify candidate non-shared environment processes in the transition to middle childhood. We estimated effects within and between informants, while also examining change over a 1-year period.

As is typical in family studies of children's behaviour, we began with an analysis of parents' ratings of the parent–child relationship and of children's behaviors. We examined whether differences in mothers' self-ratings of positivity and negativity would be associated with differences in mothers' ratings of the twins' behaviour problems. There was evidence that mothers reported more negative feelings and less positive feelings towards the twin she rated as higher in externalizing behavioural problems. This pattern of effect sizes was very similar to those reported by Asbury *et al.* (2003) and Deater-Deckard *et al.* (2001), based on younger twins. Thus, at least within the mind of the same parent, genetically identical twins are differentiated from each other in their behavioural and emotional problems, and those differences are associated with self-reported differential hostility and warmth in expected ways.

This replication is highly suggestive of a candidate non-shared environmental process. However, because this finding is based on one informant, it could also be simply due to the fact that the parent has developed child-specific conceptions of her or his relationship with each child—something that may or may not reflect the actual inter-personal dynamics that may serve to differentiate sibling children. To address this issue, more objective measures of parenting and child behaviour are needed. The majority of the studies that have sought to identify non-shared environmental processes have relied on questionnaires. To our knowledge, only a few have used naturalistic observations of dyadic parent–child interactions and child maladjustment (Deater-Deckard *et al*., 2001; Pike *et al*., 1996).

In the current study, results indicated that observer-rated differential maternal negativity was significantly associated with observer-rated differences in child non-compliant and oppositional behaviour, at both assessments. Thus, the twin who was rated by an observer as

showing more of these difficult behaviors during the in-home interaction (compared with her co-twin) was also the recipient of higher levels of observer-rated maternal negativity, relative to her co-twin. Furthermore, the effect size (in the 0.20 range) was comparable to that detected for mothers' reports, suggesting that this potential candidate non-shared environment process was not simply due to informant effects. This is consistent with several prior studies that have used interviewer and observer reports in addition to parents' ratings (Caspi *et al*., 2004; Deater-Deckard *et al*., 2001).

A similar pattern across the two waves and across parents' and observers' reports also was found for differential maternal positivity, and child externalizing problems and positive engagement. The twin who was the recipient of higher levels of maternal positivity also was reported as lower in externalizing problems and observed as higher in positive engagement during mother–child interaction. This pattern replicated the findings of a previous study of preschool-aged MZ twins that also used the PARCHISY coding system for rating observed mother–child interactions and child behaviour (Deater-Deckard *et al*., 2001). Thus, with respect to child externalizing problems and observed non-compliant oppositional behaviour and positive engagement, we found clear evidence of modest to moderate candidate non-shared environment processes that usually were present at both assessments.

In contrast, no discernible replicated candidate non-shared environment processes were found for child internalizing. This was unexpected, because non-shared environmental variance is more substantial for anxious/depressive symptoms than it is for externalizing problems (Eley, Deater-Deckard, Fombonne, Fulker, & Plomin, 1998; Silberg *et al*., 1999) and because there are well-established statistical associations between high maternal negativity, low maternal positivity, and child internalizing symptoms in family studies (Aunola & Nurmi, 2005; Low & Stocker, 2005). However, the finding is not surprising, given known limitations to measuring children's internalizing problems. Parents' reports of child internalizing problems—especially for pre-pubescent children—typically show only modest convergence with teachers' and children's reports, suggesting that it is difficult for adults to reliably assess individual differences in children's depressive and anxious symptoms (Eley *et al*., 1998). This may be a particularly acute problem when assessing twin differences and analysing change over time, because the reliability of difference scores is constrained in part by the reliability of each twin's original score. Thus, it remains to be seen whether replicable candidate non-shared environmental processes for pre-pubescent children's anxious and depressive symptoms can even be identified.

Change Over Time

The candidate non-shared environmental processes detected at each time point and described above are consistent with the literature. However, to our knowledge the current study was the first that also tested whether the same non-shared environmental processes found at one point in time could also account for changes over time in the degree of MZ twin differentiation in behavioural and emotional adjustment. This addresses a gap in the literature, because theory regarding differential parenting and its effects is inherently developmental. Over time, as each parent–child relationship within the family develops, the distinct qualities of each parent–child relationship in the family become more stable as the individual attributes (temperament, personality, interests) of each child also become more stable (Deater-Deckard, in press; Dunn & Plomin, 1990). Because so much of the non-genetic variance in children's externalizing and internalizing symptoms is non-shared, this implies that non-shared environmental mechanisms within families should be able to account for change in sibling differences over time—not only at a single point in time.

Consistent with our hypothesis, when we estimated correlations between changes over 1 year in identical twin differences in behaviour, and changes over the same period in identical twins'

maternal parenting, moderate (0.20 to 0.50 range) and significant effects were found. For analyses within informant (observer or mother, as reported in Table 2), every effect that replicated across the first and second assessments (i.e. the correlation was significant at time 1 and time 2) was also significant in the analysis of change from time 1 to time 2. Of all the significant correlations in Table 2, 14 were in the expected direction, and the average correlation was±0.31, $p<0.05$. Thus, within each family, the child who was showing more conduct problems or less positive engagement *over time* was also experiencing increasing levels of maternal negativity and decreasing levels of maternal positivity relative to her genetically identical co-twin. This means that the candidate non-shared environmental processes detected in the cross-sectional analyses generalized to explaining changing twin differences over a 1-year period.

Examining longitudinal non-shared environmental processes between informants (e.g. mothers' ratings of differential parenting and observers' ratings of twin differences in child behaviour; observers' ratings of differential parenting and mothers' ratings of twin differences in child behaviour) was a far more stringent test, and yielded different results. No significant and replicated patterns of covariation were found at either time point or in analysis of change over time when examining between-informant data. In Table 3, only one of the 24 estimated correlations was significant, and only 11 of the 24 were in the expected direction. The average correlation was±0.09, a non-significant effect size in the current study. The lack of significant associations across informants is consistent with Pike *et al.*'s (1996) study of adolescent MZ twins, and is suggestive of informant and method effects. It suggests that although non-shared environmental processes that operate over time appear to be detectable, the effects may not be large or consistent enough across settings to be detectable when using a conservative test.

However, estimating non-shared environmental processes across informants may be overly conservative because it minimizes the effects of any potentially meaningful within-context, within-time mechanisms (an undesirable artefact) while also removing the effects of rater bias (a desirable design feature). Bear in mind that for observers' ratings, a different observer rated each twin–mother interaction within any given family—within each time point and across time as well. Although the structure of the mother–child interactions constrained child and maternal behaviour, it is unlikely that any systematic rater biases contributed to producing or inflating these effect sizes, because different observers rated each mother–child pair. When considered with the replication of effects within and across time (as well as replication of some of the effects found based on mothers' ratings), this suggests that the processes linking mother–child relationship quality and child behaviors are representative of meaningful non-shared environmental mechanisms.

There are several shortcomings of this study that should be considered. MZ twins are very similar when compared with other types of siblings, and their families may represent a different sibling context than those of fraternal twins and non-twin siblings. Therefore, the non-shared environment processes that we have identified may not generalize to all families. Furthermore, because MZ twin differences are relatively small when compared with other types of siblings, the effect sizes that we detected may be attenuated, providing underestimation of the magnitude of these non-shared environmental effects. Additionally, because of the correlational nature of the MZ difference method we cannot assume specific causal relations in either direction (parent to child, child to parent). However, we are able to examine how change in differences in the measured environment and differences in measured behaviour impacts the observed associations over time. Another limitation of this study is that the data are drawn from a volunteer community sample of families with twins, and few of the children have clinically relevant levels of problem behaviors. Our assumption is that the processes that we are examining in this sample of healthy children and well-functioning families are representative of the processes that produce or serve to sustain clinically meaningful levels of child

maladjustment, although there is no way for us to test this assumption in the current study. Only tests for replication based on large population-based twin samples that include representation of behaviorally and emotionally disordered children can address this concern. Lastly, due to limited data for father–child interactions we were not able to examine whether non-shared environmental mechanisms operate in the same fashion for mother–child interactions and father–child interactions.

Implications

Caveats aside, the findings provide some of the strongest evidence to date that differential maternal warmth and hostility—self-perceived and observed by others—are critically important aspects of sibling differentiation in problematic and adaptive behaviours, above and beyond any genetic and shared environmental influences. The parent and child effects that are operating to produce fairly stable relationship dynamics and child behaviors within families can serve to further differentiate siblings' behaviors and their relationships with the same parent over time—in addition to any effects arising from genetic differences between children in the same family. In middle childhood, differential parenting appears to be an important part of several non-shared environmental processes. As children proceed through middle childhood, differential experiences involving other social influences—peers in particular—will become as or more important in accounting for non-shared environment in adaptive and maladaptive behaviours. These effects, coupled with systematic shared environmental influences that lead to sibling similarity, work together to create the individual differences in children's attributes within and between families.

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References

Achenbach, TM. Manual for the teacher's report form and 1991 profile. Burlington, VT: University of Vermont, Department of Psychiatry; 1991.

Asbury K, Dunn J, Pike A, Plomin R. Nonshared environmental influences on individual differences in early behavioral development: A monozygotic twin differences study. Child Development 2003;74:933–943. [PubMed: 12795399]

Asbury K, Dunn J, Plomin R. Birthweight-discordance and differences in early parenting relate to monozygotic twin differences in behavior problems and academic achievement at age 7. Developmental Science 2006a;9:F22–F31. [PubMed: 16472310]

Asbury K, Dunn J, Plomin R. The use of discordant MZ twins to generate hypotheses regarding non-shared environmental influences on anxiety in middle childhood. Social Development 2006b;15:564–570.

Aunola K, Nurmi JE. The role of parenting styles in children's problem behavior. Child Development 2005;76:1144–1159. [PubMed: 16274431]

Brophy M, Dunn J. What did mummy say? Dyadic interaction between young 'hard to manage' children and their mothers. Journal of Abnormal Child Psychology 2002;30:103–112. [PubMed: 12002392]

Burt SA, McGue M, Iacono WG, Krueger RF. Differential parent–child relationships and adolescent externalizing symptoms: Cross-lagged analyses within a monozygotic twin differences design. Developmental Psychology 2006;42:1289–1298. [PubMed: 17087561]

Caspi A, Moffit TE, Morgan J, Rutter M, Taylor A, Arsenault L, et al. Maternal expressed emotion predicts children's antisocial behavior problems: Using monozygotic-twin differences to identify environmental effects on behavioral development. Developmental Psychology 2004;2:149–161. [PubMed: 14979757]

Conger KJ, Conger RD. Differential parenting and change in sibling differences in delinquency. Journal of Family Psychology 1994;8:287–302.

Corapci F, Radan AE, Lozoff B. Iron deficiency in infancy and mother–child interaction at 5 years. Journal of Developmental & Behavioral Pediatrics 2006;27:371–378. [PubMed: 17041272]

Crosnoe R, Elder GH Jr. Adolescent twins and emotional distress: The interrelated influence of nonshared environment and social structure. Child Development 2002;73:1761–1774. [PubMed: 12487492]

Deater-Deckard, K. The Parent Feelings Questionnaire. London: Institute of Psychiatry; 1996.

Deater-Deckard, K. Parenting the genotype. In: McCartney, K.; Weinberg, R., editors. Experience and development: A festschrift in honor of Sandra Scarr. London: Taylor and Francis; in press

Deater-Deckard K, Pike A, Petrill SA, Cutting AL, Hughes C, O'Connor TG. Nonshared environmental processes in social–emotional development: An observational study of identical twin differences in the preschool period. Developmental Science 2001;4:F1–F6.

Deater-Deckard, K.; Pylas, M.; Petrill, SA. Parent– child interaction coding system. London, UK: Institute of Psychiatry; 1997.

Denham SA, Workman E, Cole PM, Weissbrod C, Kendziora KT, Zahn-Waxler C. Prediction of externalizing behavior problems from early to middle childhood: The role of parental socialization and emotion expression. Development and Psychopathology 2000;12:23–45. [PubMed: 10774594]

Dunn, J.; Plomin, R. Separate lives: Why siblings are so different. New York: Basic Books; 1990.

Eley TC, Deater-Deckard K, Fombonne E, Fulker DW, Plomin R. An adoption study of depressive symptoms in middle childhood. Journal of Child Psychology and Psychiatry 1998;39:337–345. [PubMed: 9670089]

Fagan AA, Najman JM. Associations between early childhood aggression and internalizing behavior for sibling pairs. Journal of the American Academy of Child and Adolescent Psychiatry 2003;42:1093–1100. [PubMed: 12960709]

Feinberg M, Hetherington EM. Differential parenting as a within-family variable. Journal of Family Psychology 2001;15:22–37. [PubMed: 11322082]

Heller TL, Baker BL. Maternal negativity and children's externalizing behavior. Early Education & Development 2000;11:483–498.

Hughes C, Ensor R. Executive function and theory of mind in 2-year olds: A family affair? Developmental Neuropsychology 2005;28:645–668. [PubMed: 16144431]

Kendler KS, Jacobson K, Myer JM, Eaves LJ. A genetically informative developmental study of the relationship between conduct disorder and peer deviance in males. Psychological Medicine 2008;38:1001–1011. [PubMed: 17935643]

Liang H, Eley TC. A monozygotic twin differences study of nonshared environmental influence on adolescent depressive symptoms. Child Development 2005;76:1247–1260. [PubMed: 16274438]

Low SM, Stocker C. Family functioning and children's adjustment: Associations among parents' depressed mood, marital hostility, parent–child hostility, and children's adjustment. Journal of Family Psychology 2005;19:394–403. [PubMed: 16221020]

Marks DJ, Cyrulnik SE, Kera EC, Berwid OG, Santra A, Halperin JM. Objective and subjective assessments of parenting in hyperactive preschoolers. Infant and Child Development 2006;15:439–442.

McGuire S, Dunn J, Plomin R. Maternal differential treatment of sibling and children's behavioral problems: A longitudinal study. Development and Psychopathology 1995;7:515–528.

Park JH, Essex MJ, Zahn-Waxler C, Armstrong JM, Klein MH, Goldsmith HH. Relational and overt aggression in middle childhood: Early child and family risk factors. Early Education and Development 2005;16:233–257.

Pike A, Reiss D, Hetherington EM, Plomin R. Using MZ differences in the search for nonshared environmental effects. Journal of Child Psychology and Psychiatry and Allied Sciences 1996;37:695–704.

Plomin R, Daniels D. Why are children in the same family so different from one another? Behavioral and Brain Sciences 1987;10:1–59.

Plomin, R.; DeFries, J.; Craig, I.; McGuffin, P., editors. Behavioral genetics in the postgenomic era. Washington, DC: APA Books; 2003.

Reiss, D.; Neiderhiser, J.; Hetherington, EM.; Plomin, R. The relationship code: Deciphering genetic and social influences on adolescent development. Cambridge, MA: Harvard University Press; 2000.

Roismann GI, Fraley RC. A behavior-genetic study of parenting quality, infant attachment security, and their covariation in a nationally representative sample. Developmental Psychology 2008;44:831–839. [PubMed: 18473647]

Rowe DC, Plomin R. The importance of nonshared (E1) environmental influences in behavioral development. Developmental Psychology 1981;17:517–531.

Saudino KJ, Carter AS, Purper-Ouakil D, Gorwood P. The etiology of behavioral problems and competencies in very young twins. Journal of Abnormal Psychology 2008;117:48–62. [PubMed: 18266485]

Scarr S, McCartney K. How people make their own environments: A theory of genotype → environment effects. Child Development 1983;54:1333–1353.

Silberg J, Pickles A, Rutter M, Hewitt J, Simonoff E, Maes H, et al. The influence of genetic factors and life stress on depression among adolescent girls. Archives of General Psychiatry 1999;53:225–232. [PubMed: 10078499]

Stocker C. Differences in mothers' and fathers' relationships with siblings: Links with children's behavior problems. Development and Psychopathology 1995;7:499–513.

Turkheimer E, Waldron M. Nonshared environment: A theoretical, methodological and quantitative review. Psychological Bulletin 2000;126:78–108. [PubMed: 10668351]

Table 1

Means and standard deviations of observers' and mothers' ratings

	Time 1						Time 2					
	Twin 1			Twin 2			Twin 1			Twin 2		
	M	SD	Min/Max	*M*	SD	Min/Max	*M*	SD	Min/Max	*M*	SD	Min/Max
Observer ratings												
Child neg behaviour	1.33	0.43	1.00–3.33	1.21	0.36	1.00–2.83	1.26	0.27	1.00–2.00	1.20	0.27	1.00–2.17
Child pos engage	2.17	0.50	2.17–4.33	2.33	0.69	2.33–5.33	3.39	0.66	1.83–5.00	3.85	0.73	2.33–6.00
Mother positivity	3.92	0.70	2.67–6.17	4.01	0.63	2.67–5.50	4.35	0.94	2.00–6.33	4.49	0.97	2.33–6.33
Mother negativity	1.24	0.41	1.00–3.25	1.12	0.18	1.00–1.75	1.20	0.40	1.00–3.00	1.17	0.31	1.00–2.25
Mother ratings												
Externalizing	6.19	5.70	0.00–23.00	6.91	5.24	0.00–21.00	5.61	4.81	0.00–18.00	6.51	5.14	0.00–19.00
Internalizing	4.05	4.27	0.00–20.00	4.91	5.25	0.00–18.00	4.05	4.02	0.00–17.00	4.63	4.92	0.00–25.00
Mother negativity	−0.18	0.80	−1.52–2.02	−0.10	0.86	1.35–2.80	−0.04	0.73	−1.52–2.01	0.80	−0.03	−1.26–2.18
Mother positivity	0.20	0.70	−2.42–1.45	0.18	0.89	−4.56–1.49	0.13	0.82	−3.80–1.66	0.07	0.91	−4.56–1.39

Table 2

Correlations between monozygotic twin (MZ) relative difference scores for within raters

	Mother negativity			Mother positivity		
	Time 1	**Time 2**	**Change**	**Time 1**	**Time 2**	**Change**
Observer ratings (PARCHISY)						
Child negative behaviour	0.24*	0.25*	0.29**	0.14	−0.27**	−0.01
Child positive engagement	−0.13	−0.28**	−0.11	0.45**	0.59**	0.51**
	PFQ-Negativity			PFQ-Positivity		
	Time 1	Time 2	Change	Time 1	Time 2	Change
Mother ratings						
CBCL-Externalizing	0.29**	0.20*	0.30**	30.23*	−0.21*	−0.29**
CBCL-Internalizing	−0.17	0.02	−0.01	−0.07	−0.05	0.05

One-tailed *p*-values:

* $p<0.05$,

** $p<0.01$.

Table 3

Correlations between monozygotic twin (MZ) relative difference scores for across raters

	Mother Ratings					
	PFQ-Negativity			PFQ-Positivity		
	Time 1	Time 2	Change	Time 1	Time 2	Change
Observer ratings (PARCHISY)						
Child negative behaviour	−0.09	−0.07	0.02	0.11	0.00	0.16
Child positive engagement	−0.03*	−0.09	−0.08	−0.05	−0.13	−0.12
	CBCL-Externalizing			CBCL-Internalizing		
	Time 1	Time 2	Change	Time 1	Time 2	Change
Mother negativity	−0.19	0.21*	0.01	−0.05	−0.02	−0.02
Mother positivity	0.12	0.16	0.04	0.16	0.07	0.05

One-tailed *p*-values:

* $p<0.05$.