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Genetic contributions to continuity and change in attachment security: a prospective, longitudinal investigation from infancy to young adulthood

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Background: Longitudinal research has demonstrated that individual differences in attachment security show only modest continuity from infancy to adulthood. Recent findings based on retrospective reports suggest that individuals' genetic variation may moderate the developmental associations between early attachment–relevant relationship experiences and adult attachment security. The purpose of this study was to use a prospective, longitudinal design to investigate genetic contributions to continuity and changes in attachment security from infancy to young adulthood in a higher risk sample. **Methods:** Infant attachment security was assessed using the Strange Situation Procedure at 12 and 18 months. Adults' general attachment representations were assessed using the Adult Attachment Interview at ages 19 and 26. Romantic attachment representations were assessed with the Current Relationship Interview (CRI) at ages 20–21 and ages 26–28. Individuals were genotyped for variants within the oxytocin receptor (OXTR), dopamine D4 receptor (DRD4), and serotonin transporter linked polymorphic region (5-HTTLPR) . **Results:** The continuity of attachment security from infancy into young adulthood was consistently moderated by OXTR genetic variation. Infant attachment security predicted the security of adults' general and romantic attachment representations only for individuals with the OXTR G/G genotype. This interaction was significant when predicting adult attachment security as measured by the Adult Attachment Interview at ages 19 and 26 and the CRI at ages 26–28. Dopamine D4 receptor and 5-HTTLPR genetic variation did not consistently moderate the longitudinal associations between attachment security during infancy and adulthood. **Conclusions:** This study provides initial longitudinal evidence for genetic contributions to continuity and change in attachment security from infancy to young adulthood. Genetic variation related to the oxytocin system may moderate the stability of attachment security across development. **Keywords:** Attachment, continuity, development, genetics.

Introduction

Attachment relationships are believed to play an important role in individuals' lives from the cradle to the grave (Bowlby, 1988). During infancy, individuals are expected to develop relatively secure or insecure attachment relationships based on the level of sensitive care they receive from their caregivers (Ainsworth, Blehar, Waters, & Wall, 1978). The security of the infant–caregiver attachment relationship is thought to serve as the foundation for individuals' later expectations and beliefs about close relationships. More specifically, infants who are securely attached to their caregivers are expected to develop more secure mental representations of attachment and attachment relationships during adulthood, as reflected by their ability to discuss attachment–relevant experiences in a coherent and emotionally well-regulated manner.

These theoretical predictions have inspired numerous longitudinal investigations of the continuity of attachment security across development. Although individual studies have yielded mixed results (e.g., Grossmann, Grossmann, & Waters, 2005; Waters, Weinfield, & Hamilton, 2000; Weinfield, Sroufe, & Egeland, 2000), meta-analytic evidence indicates that there is a statistically significant but modest degree of continuity in attachment security from infancy to young adulthood (Fraley, 2002). However, the moderate size of these developmental associations indicates that infant attachment experiences do not determine the security of adults' attachment representations and developmental changes in attachment security are common.

At the same time, there has also been increasing interest in examining genetic influences on attachment. Most of the research in this area though has focused on genetic contributions to attachment security during infancy (e.g., Luijk et al., 2011; Raby et al., 2012), resulting in a relative lack of understanding of the potential correlates of attachment security in adulthood or the continuity of attachment security across development. Nevertheless, it has long been speculated that inherited factors and characteristics may be involved in the development of attachment security. For example, Bowlby (1988) noted that 'heritable differences' may shape individuals' responses to their early relationship experiences (p. 9). Main (1999) also recommended the use of genetically informed designs to understand the etiology of adults' attachment representations. Other

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scholars have called attention to the need to consider how children's biologically based temperamental characteristics may moderate the continuity of attachment security across development (Fraley, 2002; Thompson, 2006; Waters et al., 2000).

Behavioral genetic investigations of adult attachment security offer provisional evidence that heritable factors may contribute to attachment continuity and change. For example, available evidence from twin studies indicates that similarity in the security of adults' attachment representations is greatest for genetically identical twins (Torgersen, Bjorg, & Sommerstad, 2007; cf. Constantino et al., 2006), suggesting that adult attachment security may be at least partially influenced by heritable factors. However, genetic factors do not appear to account for all of the similarities in siblings' attachment representations (e.g., Caspers, Yucuis, Troutman, Arndt, & Langbehn, 2007), indicating that adult attachment security is also shaped by the shared family environment.

A small number of molecular genetic investigations have built on these behavioral genetic findings and examined how specific genetic factors and early relationship experiences work together to shape attachment security in adulthood. Findings from these studies have supported the idea that genetic factors may moderate the connections between early relationship experiences and adult attachment security (Bakermans-Kranenburg, van IJzendoorn, Caspers, & Philibert, 2011; Reiner & Spangler, 2010). For example, Reiner and Spangler (2010) observed that the dopamine D4 receptor (DRD4) 7-repeat variant was associated with greater attachment security when adults reported experiencing an emotionally unsupportive childhood caregiving environment. These investigations have been limited though by the reliance on retrospective measures of earlier parent–child experiences, which are subject to recall bias and may not accurately reflect previous caregiving experiences (Roisman, Fortuna, & Holland, 2006). Thus, there is a need for replication using prospective, longitudinal designs.

This study included three genetic variants that were selected a priori based on their empirical and theoretical relevance to adult attachment. The DRD4 number repeat polymorphism is thought to shape individuals' susceptibility to risks and rewards (Belsky & Pluess, 2009) and has been previously been tied to adult attachment security (Reiner & Spangler, 2010). The serotonin transporter linked polymorphic region (5-HTTLPR) has been associated with individual differences in negative emotionality, with the short allele conferring a heightened sensitivity to stressful events (e.g., Raby et al., 2012). Although this genetic variant does not appear to be directly associated with the security of adults' attachment representations (Reiner & Spangler, 2010), 5-HTTLPR may moderate the continuity of attachment security across development. Indeed, 5-HTTLPR has been observed to moderate infant attachment security's influence on developmental outcomes during childhood (e.g., Kochanska, Kim, Barry, & Philibert, 2011). Finally, the neuropeptide oxytocin has been connected to close relationship processes in animals and humans (Donaldson & Young, 2008; Galbally, Lewis, van IJzendoorn, & Permezel, 2011). An A/G single nucleotide polymorphism (rs53576) in the gene coding for the oxytocin receptor (OXTR) has also been associated with sensitive parenting (Bakermans-Kranenburg, & van IJzendoorn, 2008), which is closely tied to the security of adults' attachment representations.

The purpose of this study was to test the idea that genetic factors moderate continuity and change in attachment security using a prospective, longitudinal design. This study builds on earlier reports from this project demonstrating relatively modest overall stability in attachment security from infancy to young adulthood (Roisman, Collins, Sroufe, & Egeland, 2005; Weinfield et al., 2000). Measures of the security of adults' general and romantic attachment representations were collected during young adulthood and were used in this study to provide a comprehensive test of potential genetic contributions to the continuity of attachment security from infancy into young adulthood.

Method

Participants

Participants were drawn from an ongoing longitudinal study of development from infancy to adulthood (Sroufe, Egeland, Carlson, & Collins, 2005). Between 1975 and 1977, primiparous mothers living in poverty and receiving prenatal services through the local health department were recruited. At the time of the child's birth, 48% of the mothers were teenagers, 63% were single, and 34% had received less than a high school education. Sixty-seven percent of the infants were Caucasian, 21% were multiracial, 9% were African American, and 3% were Native American, Hispanic, or Asian American.

The current subsample of 143 individuals (52% female) included participants who provided DNA information and completed at least one adult attachment assessment. This subsample did not significantly differ from the original sample ($N = 267$) with respect to variables included in the analyses or sociodemographic characteristics, except for race. This subsample included fewer African Americans compared with the original sample. Race was included as a control for all analyses to prevent these sample differences from biasing the results.

Measures

Infant attachment security. The security of the infant–caregiver attachment relationship was

assessed when infants were 12 and 18 months old using the Strange Situation Procedure (Ainsworth et al., 1978). During this laboratory procedure, infants' responses to a series of mildly stressful separations and reunions with their mothers were observed. The traditional system was used to classify infants according to the organized patterns of securely attached, insecure-avoidant, or insecure-resistant. The attachment assessments at 12 and 18 months were coded by independent teams with high interrater agreement for both assessments (89% and 93%, respectively). In addition, all Strange Situation tapes still available were coded at a later time for attachment disorganization/disorientation (κ = .72, n = 35). For this study, cases classified as disorganized were coded as insecure at that assessment, irrespective of their secondary classification. Infant attachment information was aggregated by calculating the percentage of times the infant was securely attached. Infants who were insecurely attached at both time-points (31%) received a score of 0%, those who were securely attached at one time-point (27%) received a score of 50%, and infants who were securely attached at both time-points (42%) received a score of 100%.

Adults' general attachment representations. The Adult Attachment Interview (AAI) was completed when participants were ages 19 and 26 to assess the security of their general representations about attachment (Main, Kaplan, & Cassidy, 1985). This semistructured interview requires participants to describe their childhood relationships with their parents and recall specific incidents of separation or rejection. Following Main and Goldwyn's (1998) guidelines, adults' AAI narratives were rated on a set of 9-point scales, including the coherence of mind scale that was used in the current analyses. The coherence of mind rating captures the extent to which adults discuss and freely evaluate their attachment-related experiences in an organized and emotionally contained manner, and this rating is commonly used as a dimensional measure of the security of adults' general attachment representations (e.g., Reiner & Spangler, 2010). Reliability for the AAI coherence ratings at age 19 (ICC = .77) and age 26 (ICC = .85) was acceptable.

Representations of adult romantic relationships. Adults' representations of their specific relationship with their current romantic partner were measured using the Current Relationship Interview (CRI; Crowell & Owens, 1996). The CRI was completed with participants who had been involved in romantic relationships for at least 4 months when the participants were ages 20–21 and ages 26–28. The relationship duration criterion was used to ensure that the romantic partnerships represented committed relationships. The average relationship length was 2.3 years at ages 20–21 and 3.7 years at ages 26–28. Sample sizes were reduced as all participants were not involved in a romantic relationship at the time of the assessment (ages 20–21, n = 74; ages 26–28, n = 70). The CRI parallels the structure and coding of the AAI, except that individuals are asked to describe their current relationship with their romantic partner and recall specific incidents of receiving and providing support. A 9-point rating of the overall coherence of adults' CRI responses was used as a dimensional measure of the security of their romantic attachment representations. The CRI transcripts were coded by independent raters who were unaware of participants' scores on the AAI. Reliability for the CRI coherence ratings at ages 20–21 (ICC = .77) and ages 26–28 (ICC = .90) was acceptable.

OXTR, DRD4, and 5-HTTLPR genetic variation. Participants provided buccal cells for DNA analysis when they were age 32. The Epicentre BuccalAmp DNA Extraction Kit was used to prepare DNA for PCR amplification, and genotyping was conducted following previously published protocols (Cicchetti & Rogosch, 2012). All samples were genotyped in duplicate for quality control. In addition, human DNA from cell lines was purchased from Coriell Cell Repositories for all representative genotypes. Genotypes were confirmed by sequencing using DTCS chemistry on an ABI 3130x1 (Applied Biosystems, Foster City, CA, USA). These and a no template control were run alongside the study samples. Any samples that were not able to be genotyped to a 95% or greater confidence level were repeated under the same conditions. Call rates for the entire sample for the OXTR, DRD4, and 5-HTTLPR genetic regions were 100%, 98%, and 99%, respectively.

The OXTR genotype distribution (A/A, n = 18; A/G, n = 66; G/G, n = 59) was in the Hardy–Weinberg equilibrium, $\chi^2(1) = 0.00$, $p = 1.00$. Because of the low frequency of the A/A genotype, individuals with A/A or A/G genotypes were combined in all analyses. The DRD4 genotype distribution was in the Hardy–Weinberg equilibrium, $\chi^2(1) = 0.51$, $p = .48$. Individuals with at least one copy of the 7-repeat allele (36%) were combined for analyses. The triallelic 5-HTTLPR genotype was used because an additional A > G single nucleotide polymorphism in the long allele results in gene expression levels that are comparable to the short allele (Hu et al., 2005). Consistent with prior work (e.g., Raby et al., 2012), the L_G and S alleles were grouped together as S′ alleles, and the L_A allele was designated as L′. The 5-HTTLPR triallelic genotype (S′/S′, n = 37; S′/L′, n = 67; L′/L′, n = 39) was in the Hardy–Weinberg equilibrium, $\chi^2(3) = 1.47$, $p = .39$.

Missing data. Three (2.1%) participants lacked infant attachment data, nine (6.3%) lacked age 19 AAI data, and six (4.2%) lacked age 26 AAI data. These values were assumed to be missing at random, and missing values were estimated using data

imputation techniques. The missing CRI values could not be assumed to be missing at random, for much of the missingness was because the participants were not involved in committed romantic relationships at the time of the young adult assessments. As a result, the missing CRI values were not imputed.

Analytic approach. Linear regression models were used to evaluate whether genetic variation moderated the continuity of attachment security from infancy to adulthood. Separate linear regressions were conducted for adults' general attachment representations at ages 19 and 26 and their romantic attachment representations at ages 20–21 and ages 26–28. Terms representing the main effects of infant attachment security and genetic variation were entered in an initial step, followed by terms representing the interactions between infant attachment security and each of the genetic variants. To reduce the number of analyses, the three genetic variants were included in each of the models. Sex and race were included as controls in all analyses to correct for potential confounds due to population stratification and sex differences.

Results

Correlations between genetic variation and attachment security during infancy were evaluated. Infant attachment security was not significantly associated with OXTR, DRD4, or 5-HTTLPR variation, indicating that infant attachment security and genetic variation could be considered relatively independent factors.

Genetic moderation of continuity between infant attachment security and the security of adults' general attachment representations

We first evaluated whether genetic variation in OXTR, 5-HTTLPR, and DRD4 regions moderated the developmental associations between infant attachment security and the security of adults' general attachment representations, as measured by coherence during the AAI. Although infant attachment security predicted AAI coherence at age 19 ($p = .02$), this main effect was moderated by genetic variations in OXTR ($p = .02$) and 5-HTTLPR ($p < .01$) regions (see Table 1). The interaction between infant attachment security and DRD4 was not statistically significant. Follow-up analyses for the interaction with OXTR revealed that infant attachment security predicted greater AAI coherence at age 19 among individuals with the OXTR G/G genotype ($\beta = .36$, $p < .01$; see Figure 1a). In contrast, infant attachment security was not significantly associated with later AAI coherence for individuals carrying an A allele ($\beta = .04$, $p = .72$). As for 5-HTTLPR, infant attachment security predicted greater AAI coherence among individuals carrying two S′ alleles ($\beta = .50$, $p < .001$). Associations between infant and adult attachment security were not significant for S′/L′ ($\beta = .16$, $p = .20$) or L′/L′ ($\beta = -.04$, $p = .81$) carriers.

The second set of analyses indicated that OXTR variation also moderated the longitudinal association

Table 1 Main and interactive effects of infant attachment security and genetic variation when predicting the security of adults' general attachment representations as assessed with Adult Attachment Interview

	B	*SE*	*β*
General attachment representations at age 19			
Infant attachment security	0.77	.34	.19*
OXTR	0.08	.28	.02
DRD4	−0.36	.30	−.10
5-HTT	0.26	.19	.11
Infant attachment security × OXTR	1.48	.66	.18*
Infant attachment security × DRD4	0.62	.67	.08
Infant attachment security × 5-HTT	1.20	.44	.23*
General attachment representations at age 26			
Infant attachment security	0.57	.38	.13
OXTR	0.15	.32	.04
DRD4	0.51	.33	.13
5HTT	0.05	.23	.02
Infant attachment security × OXTR	1.71	.75	.19*
Infant attachment security × DRD4	1.47	.80	.16
Infant attachment security × 5-HTT	−0.02	.52	−.01

All models control for sex and race.
*$p < .05$.

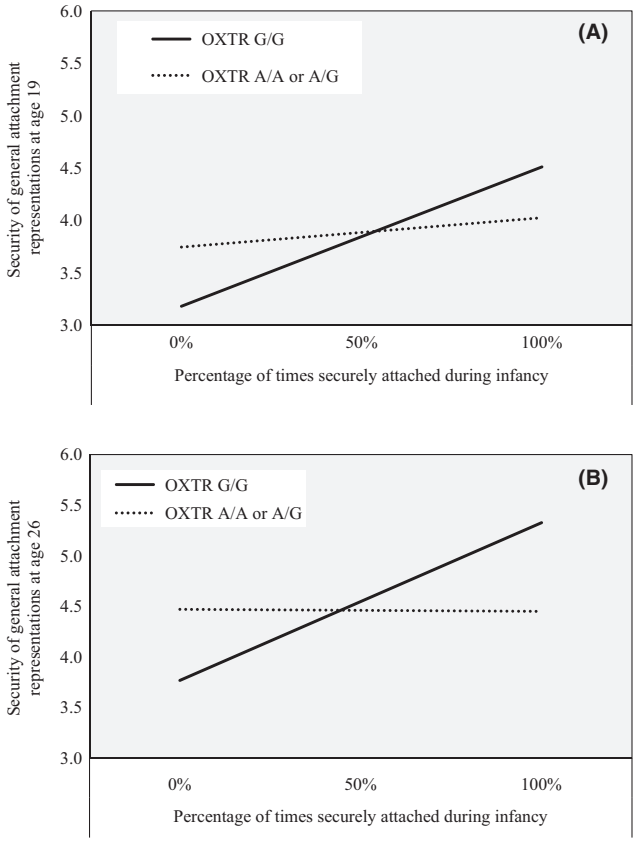

Figure 1 Oxytocin receptor (OXTR) moderation of the longitudinal associations between infant attachment security and the security of adults' general attachment representations at ages 19 (a) and 26 (b)

between infant attachment security and AAI coherence at age 26 ($p = .02$). Infant attachment security predicted greater coherence during the age 26 AAI for individuals with the OXTR G/G genotype ($\beta = .36$, $p < .01$; see Figure 1b). For individuals carrying an OXTR A allele, infant attachment security was not significantly associated with adult attachment ($\beta = -.03$, $p = .79$). Interaction terms for infant attachment and 5-HTTLPR and DRD4 were not statistically significant for age 26 AAI coherence.

Genetic moderation of continuity between infant attachment security and the security of adults' romantic attachment representations

We next evaluated whether genetic variation also moderated the developmental associations between infant attachment security and the security of adults' representations of their current romantic relationship partner, as measured by their coherence during the CRI. Neither infant attachment security nor genetic variation independently predicted coherence during the CRI at ages 20–21 (see Table 2). Interactions involving infant attachment and genetic variation also failed to reach statistical significance. Although the interaction between OXTR variation and infant attachment was not statistically significant ($p = .12$), exploratory analyses of the associations between infant and CRI coherence based on OXTR genotype were conducted because of the consistent moderation of the connections between infant attachment security and coherence during AAI. Similar to the findings related to the AAI, the longitudinal association between infant attachment security and CRI coherence approached statistically significance for individuals with the OXTR G/G genotype ($\beta = .31$, $p = .06$; see Figure 2a). For individuals carrying an OXTR A allele, infant attachment security did not significantly predict the security of adults' romantic attachment representations ($\beta = -.05$, $p = .74$).

When predicting coherence during the CRI at ages 26–28, the interaction between infant attachment security and OXTR was significant ($p = .03$; see Table 2). Infant attachment security predicted greater CRI coherence for individuals with the OXTR G/G genotype ($\beta = .42$, $p < .01$; see Figure 2b). For individuals carrying an OXTR A allele, infant attachment security was not associated with adults' romantic attachment representations ($\beta = -.05$, $p = .72$). Interaction terms for infant attachment and 5-HTTLPR and DRD4 were not statistically significant.

Table 2 Main and interactive effects of infant attachment security and genetic variation when predicting the security of adults' romantic attachment representations as assessed with the Current Relationship Interview

	B	*SE*	*β*
Romantic attachment representations at ages 20–21[a]			
Infant attachment security	0.34	.43	.09
OXTR	−0.33	.36	−.11
DRD4	−0.34	.35	−.11
5HTT	0.05	.25	.02
Infant attachment security × OXTR	0.94	.85	.12
Infant attachment security × DRD4	−1.30	.84	−.17
Infant attachment security × 5HTT	0.82	.62	.15
Romantic attachment representations at ages 26–28[b]			
Infant attachment security	0.84	.58	.17
OXTR	0.20	.47	.05
DRD4	0.26	.48	.06
5HTT	−0.36	.34	−.11
Infant attachment security × OXTR	2.23	1.05	.23*
Infant attachment security × DRD4	0.56	1.32	.05
Infant attachment security × 5HTT	−0.03	.91	−.01

All models control for sex and race;
a$n = 74$.
b$n = 70$.
*$p < .05$.

Additional analyses

Because OXTR moderated the longitudinal associations between infant attachment security and coherence during the AAI at both ages, analyses predicting age 26 AAI coherence were repeated after controlling for AAI coherence at age 19. There was significant stability in the AAI coherence ratings from ages 19 to 26 ($\beta = .34$, $p < .001$), and the interaction between infant attachment security and OXTR was not a significant predictor of AAI coherence at age 26

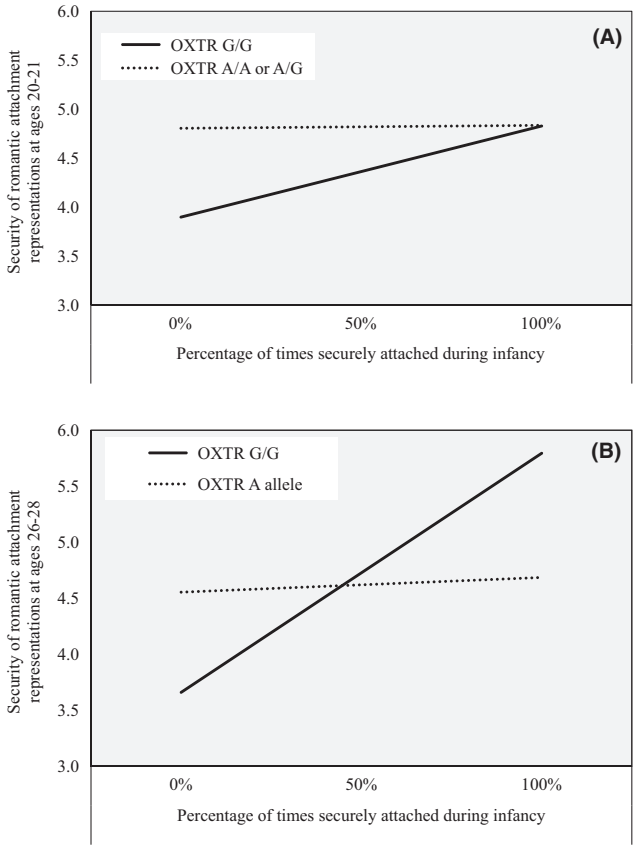

Figure 2 Oxytocin receptor (OXTR) moderation of the longitudinal associations between infant attachment security and the security of adults' romantic attachment representations at ages 20–21 (a) and ages 26–28 (b)

after controlling for AAI coherence at age 19 ($\beta = .11$, $p = .20$). Similarly, CRI coherence at ages 26–28 was predicted by AAI coherence at age 26 ($\beta = .42$, $p < .001$), and the interaction between infant attachment security and OXTR was not a significant predictor of ages 26–28 CRI coherence ($\beta = .14$, $p = .21$) after controlling for age 26 AAI coherence. Altogether, these findings suggest that the interaction between infant attachment security and OXTR predicts the variance that is shared across the various measures of adult attachment and is not specific to any one assessment.

Discussion

This study evaluated whether specific genetic factors contribute to continuity and change in attachment security across development. We observed that variation within the OXTR gene moderated the developmental associations between the security of the infant–caregiver attachment relationship and the security of adults' general representations of attachment. Specifically, continuity in attachment security was observed only for individuals with the OXTR G/G genotype. Changes in attachment security were more common among carriers of the OXTR A allele. Furthermore, OXTR variation also moderated the developmental associations between infant attachment security and the security of adults' representations of their romantic partner at ages 26–28. Once again, attachment security during infancy predicted more secure attachment representations during adulthood only for individuals with the OXTR G/G genotype. Although the interaction between OXTR and infant attachment security did not reach the level of statistical significance when predicting the security of adults' romantic relationship representations at ages 20–21, follow-up analyses revealed that continuity in attachment security was strongest for OXTR G/G carriers. Altogether, these findings indicate that genetic variation related to the oxytocin system may have an influential role in shaping or constraining the continuity of attachment security across development.

Genetic variations within the DRD4 and 5-HTTLPR regions did not consistently moderate the developmental continuities in attachment security. Although the interaction between infant–caregiver attachment security and 5-HTTLPR was significant when predicting the security of adults' general attachment representations at age 19, a significant interaction was not observed when predicting adults' general attachment representations at age 26 or the security of adults' romantic attachment representations at ages 20–21 or ages 26–28. Thus, the interaction related to 5-HTTLPR was not robust across the various measures of adult attachment security used in this study. Based on these findings, it appears that genetic contributions to attachment continuity and change are specific to OXTR.

This study represents the first investigation of the connections between OXTR variation and the narrative-based measures of adult attachment that are commonly used within developmental psychology. That said, OXTR has been associated with adults' self-reported attachment security. Bradley et al. (2011) observed that adults who reported experiencing parental maltreatment as a child were more likely to describe themselves as being less secure in their attachment relationships if they carried the OXTR G/G genotype. Childhood maltreatment was not significantly associated with self-reported adult attachment security among OXTR A/A or A/G carriers. These findings overlap with the results of this study, for they both indicate that the associations between earlier parent–child relationship quality and adult attachment security are most pronounced for individuals carrying the OXTR G/G genotype. Still, the similarities in these findings from these two studies must be interpreted with caution because of the generally low correspondence between narrative and self-report measures of adult attachment security (Roisman et al., 2007).

The current findings are consistent with the idea that genetically based characteristics may contribute to continuity and change in attachment security across development (Bowlby, 1988; Fraley, 2002; Main, 1999; Thompson, 2006; Waters et al., 2000). Prior studies indicating that genetic factors may moderate the connections between parent–child relationship quality and adult attachment security (Bakermans-Kranenburg et al., 2011; Reiner & Spangler, 2010) have been based on adults' retrospective reports of their childhood relationship experiences. In this way, this study's prospective, longitudinal research design represents a novel extension of the research on the molecular genetic correlates of adult attachment. These research design differences may account for different pattern of findings. The results from this study were not consistent with prior retrospective-based evidence that DRD4 moderates the developmental impact of early supportive relationships for attachment security in adulthood (Reiner & Spangler, 2010). Instead, genetic variation related to the oxytocin system was observed to moderate the continuity of attachment security from infancy to young adulthood.

These findings are also consistent with the idea that the oxytocin system is involved in attachment and other close relationship processes across development (Donaldson & Young, 2008; Galbally et al., 2011). For example, intranasal oxytocin administration has been associated with improved socially related cognitions and behaviors, including social and emotional information processing, feelings of trust and security within close relationships, and socially responsive behaviors (Buchheim et al., 2009; Donaldson & Young, 2008; van IJzendoorn & Bakermans-Kranenburg, 2012). In addition, adults who carry the presumably more efficient OXTR G

variant show advantages in processing social information, psychological adjustment, and supportive interpersonal contexts (Bakermans-Kranenburg & van IJzendoorn, 2008; Ebstein, Israel, Chew, Zhong, & Knafo, 2010). Evidence from this study extends these findings by demonstrating that individuals who carry the OXTR G/G genotype are also more likely to show stability in the relative security or insecurity of their attachment patterns from infancy to young adulthood. One important task though for future research will be to identify the intermediate traits that are associated with OXTR variation and account for OXTR's role in shaping the stability of attachment security across development.

Another task for future research will be to investigate how infant attachment security, genetic factors, and later relationship experiences work together to predict adult attachment security. Prior longitudinal research has demonstrated that close relationship experiences during childhood and adolescence may contribute to the maintenance and changes in attachment security from infancy to young adulthood (e.g., Waters et al., 2000; Weinfield et al., 2000). Such findings are not incompatible with the results of this study. For example, individuals who carry an OXTR A allele may be more likely to be involved in later relationships that promote changes in attachment security or they may be more strongly impacted by them. Likewise, OXTR G/G carriers may be more likely to seek out subsequent relationships that are similar to their infant–caregiver attachment relationships or they may be less sensitive to their influence.

Given the potential importance of these findings, it is critical for them to be replicated with additional longitudinal data. Concerns have been raised about whether initial candidate gene studies represent false-positive findings (Duncan & Keller, 2011). However, this study conforms to recent recommendations for molecular genetics research, including the use of a theoretically informed longitudinal design, well-validated measures, and statistical controls for potential population stratification. Moreover, the relative consistency of the interaction between OXTR and infant attachment security across both measures of the adult attachment security, each collected at two different assessments, yields greater confidence in the validity of these findings.

This study advances our understanding of attachment across the life course by providing initial longitudinal evidence that genetic factors may shape continuity and change attachment security or insecurity across development. The current findings support theoretical hypotheses about the role of biological factors in attachment continuity and change and provide insights for further multilevel research on attachment across the life span. More generally, this study also illustrates the value of incorporating multiple levels of analysis into our developmental models of attachment. It is our belief that doing so will enrich our understanding of the complex developmental processes accounting for stability and change in attachment across development.

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Key points

- Prior studies demonstrate modest developmental continuity between attachment security during infancy and adulthood.
- Retrospective-based evidence indicates that genetic variation may moderate associations between earlier parent–child relationship experiences and adult attachment security.
- Genetic moderation of the continuity of attachment security from infancy to young adulthood was investigated using a prospective, longitudinal design.
- Variation in the OXTR gene interacted with infant attachment security to predict multiple representational measures of attachment security during young adulthood.
- Individuals with the OXTR G/G genotype demonstrated significant continuity in attachment security from infancy to young adulthood.
- Genotypic variation related to the oxytocin system may shape the continuity from attachment security within the infant–caregiver relationship with attachment security during young adulthood.

References

Ainsworth, M.D.S., Blehar, M., Waters, E., & Wall, S. (1978). *Patterns of attachment: A psychological study of the strange situation*. Hillsdale NJ: Lawrence Erlbaum Associates.

Bakermans-Kranenburg, M.J., & van IJzendoorn, M.H. (2008). Oxytocin receptor (OXTR) and serotonin transporter (5-HTT) genes associated with observed parenting. *Social Cognitive and Affective Neuroscience*, *3*, 128–134.

Bakermans-Kranenburg, M.J., van IJzendoorn, M.H, Caspers, K., & Philibert, R. (2011). DRD4 genotype moderates the impact of parental problems on unresolved loss or trauma. *Attachment and Human Development*, *13*, 253–269.

Belsky, J., & Pluess, M. (2009). Beyond diathesis stress: Differential susceptibility to environmental influences. *Psychological Bulletin*, *135*, 885–908.

Bowlby, J. (1988). Developmental psychiatry comes of age. *American Journal of Psychiatry*, *145*, 53–62.

Bradley, B., Westen, D., Mercer, K.B., Binder, E.B., Jovanovic, T., Crain, D., … &, Heim, C. (2011). Association between childhood maltreatment and adult emotional dysregulation in a low-income, urban, African American sample: Moderation by oxytocin receptor gene. *Development and Psychopathology*, *23*, 439–452.

Buchheim, A., Heinrichs, M., George, C., Pokorny, D., Koops, E., Henningsen, P., … & Gündel, H. (2009). Oxytocin enhances the experience of attachment security. *Psychoneuroendocrinology*, *34*, 1417–1422.

Caspers, K.M., Yucuis, R., Troutman, B., Arndt, S., & Langbehn, D. (2007). A sibling adoption study of adult attachment: The influence of shared environment on attachment states of mind. *Attachment and Human Development*, *9*, 375–391.

Cicchetti, D., & Rogosch, F.A. (2012). Gene×Environment interaction and resilience: Effects of child maltreatment and serotonin, corticotropin releasing hormone, dopamine, and oxytocin genes. *Development and Psychopathology*, *24*, 411–427.

Constantino, J.N., Chackes, L.M., Wartner, U.G., Gross, M., Brophy, S.L., Vitale, J., et al. (2006). Mental representations of attachment in identical female twins with and without conduct problems. *Child Psychiatry and Human Development*, *37*, 65–72.

Crowell, J., & Owens, G. (1996). Current relationship interview and scoring system. State University of New York at Stony Brook. Unpublished Manuscript.

Donaldson, Z.R., & Young, L.J. (2008). Oxytocin, vasopressin, and the neurogenetics of sociality. *Science*, *322*, 900–904.

Duncan, L.E., & Keller, M.C. (2011). A critical review of the first 10 years of candidate gene-by-environment interaction research in psychiatry. *The American Journal of Psychiatry*, *168*, 1041–1049.

Ebstein, R.P., Israel, S., Chew, S.H., Zhong, S., & Knafo, A. (2010). Genetics of human social behavior. *Neuron*, *65*, 831–844.

Fraley, R.C. (2002). Attachment stability from infancy to adulthood: Meta-analysis and dynamic modeling of developmental mechanisms. *Personality and Social Psychology Review*, *6*, 123–151.

Galbally, M., Lewis, A.J., van IJzendoorn, M.H., & Permezel, M. (2011). The role of oxytocin in mother-infant relations: A systematic review of human studies. *Harvard Review of Psychiatry*, *19*, 1–14.

Grossmann, K.E., Grossmann, K., & Waters, W. (2005). *Attachment from infancy to adulthood: The major longitudinal studies*. New York: Guilford.

Hu, X., Oroszi, G., Chun, J., Smith, T.L., Goldman, D., & Schuckit, M.A. (2005). An expanded evaluation of the relationship of four alleles to the level of response to alcohol and the alcoholism risk. *Alcoholism: Clinical and Experimental Research*, *29*, 8–16.

van IJzendoorn, M.H., & Bakermans-Kranenburg, M.J. (2012). A sniff of trust: Meta-analysis of the effects of intranasal oxytocin administration on face recognition, trust to in-group, and trust to out-group. *Psychoneuroendocrinology*, *37*, 438–443.

Kochanska, G., Kim, S., Barry, R.A., & Philibert, R.A. (2011). Children's genotypes interact with maternal responsive care in predicting children's competence: Diathesis–stress or differential susceptibility? *Development and Psychopathology*, *23*, 605–616.

Luijk, M., Roisman, G.I., Haltigan, J., Tiemeier, H., Booth-LaForce, C., van IJzendoorn, M.H., … &, Bakermans-Kranenburg, M.J. (2011). Dopaminergic, serotonergic, and oxytonergic candidate genes associated with infant attachment security and disorganization? In search of main and interaction effects *Journal of Child Psychology and Psychiatry*, *52*, 1295–1307.

Main, M. (1999). Epilogue. Attachment theory: Eighteen points with suggestions for future studies. In J. Cassidy & P.R. Shaver (Eds.), *Handbook of attachment: Theory, research, and clinical applications* (1st edn, pp. 845–887). New York: Guilford.

Main, M., & Goldwyn, R. (1998). *Adult attachment scoring and classification system*. University of California at Berkeley. Unpublished Manuscript.

Main, M., Kaplan, N., & Cassidy, J. (1985). Security in infancy, childhood, and adulthood: A move to the level of representation. *Monographs of the Society for Research in Child Development*, *50*, 66–104.

Raby, K.L., Cicchetti, D., Carlson, E.A., Cutuli, J.J., Englund, M.M., & Egeland, B. (2012). Genetic and caregiving contributions to infant attachment: Unique associations with distress reactivity and attachment security. *Psychological Science*, *23*, 1016–1023.

Reiner, I., & Spangler, G. (2010). Adult attachment and gene polymorphisms of the dopamine D4 receptor and serotonin transporter (5-HTT). *Attachment and Human Development*, *12*, 209–229.

Roisman, G.I., Collins, W.A., Sroufe, L.A., & Egeland, B. (2005). Predictors of young adults' representations of and behavior in their current romantic relationship: Prospective tests of the prototype hypothesis. *Attachment and Human Development*, *7*, 105–121.

Roisman, G.I., Fortuna, K., & Holland, A. (2006). An experimental manipulation of retrospectively defined earned and continuous attachment security. *Child Development*, *77*, 59–71.

Roisman, G.I., Holland, A., Fortuna, K., Fraley, R.C., Clausell, E., & Clarke, A. (2007). The Adult Attachment Interview and self-reports of attachment style: An empirical rapprochement. *Journal of Personality and Social Psychology*, *92*, 678–697.

Sroufe, L.A., Egeland, B., Carlson, E.A., & Collins, W.A. (2005). *The development of the person: The Minnesota study of risk and adaptation from birth to adulthood*. New York: Guilford Press.

Thompson, R.A. (2006). The development of the person: Social understanding, relationships, conscience, self. In W. Damon & R.M. Lerner (Eds.), *Handbook of child psychology*, (6th edn, pp. 24–98). New York: Wiley.

Torgersen, A.M., Bjorg, K.G., & Sommerstad, R. (2007). A pilot study of attachment patterns in adult twins. *Attachment and Human Development*, *9*, 127–138.

Waters, E., Weinfield, N.S., & Hamilton, C.E. (2000). The stability of attachment security from infancy to adolescence and early adulthood: General discussion. *Child Development*, *71*, 703–706.

Weinfield, N.S., Sroufe, L.A., & Egeland, B. (2000). Attachment from infancy to early adulthood in a high-risk sample: Continuity, discontinuity, and their correlates. *Child Development*, *71*, 695–702.

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