



PAPER

The development of stranger fear in infancy and toddlerhood: normative development, individual differences, antecedents, and outcomes

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Abstract

Despite implications that stranger fear is an important aspect of developing behavioral inhibition, a known risk factor for anxiety, normative and atypical developmental trajectories of stranger fear across infancy and toddlerhood remain understudied. We used a large, longitudinal data set (N = 1285) including multi-trait, multi-method assessments of temperament to examine the normative course of development for stranger fear and to explore the possibility that individual differences exist in trajectories of stranger fear development between 6 and 36 months of age. A latent class growth analysis suggested four different trajectories of stranger fear during this period. Stable, high levels of stranger fear over time were associated with poorer RSA suppression at 6 months of age. Rates of concordance in trajectory-based class membership for identical (monozygotic) and fraternal (dizygotic) twins, along with associations between atypical stranger fear development and greater anxiety-related maternal characteristics, suggested that individual differences in developmental trajectories of stranger fear may be heritable. Importantly, trajectories of stranger fear during infancy and toddlerhood were linked to individual differences in behavioral inhibition, with chronically high levels of stranger fear and sharp increases in stranger fear over time related to greater levels of inhibition than other developmental trajectories.

Research highlights

- Heterogeneous trajectories of developing stranger fear are apparent during infancy.
- Poor RSA suppression and high maternal anxiety predict atypical trajectories of stranger fear development.
- Developmental trajectories of stranger fear may be heritable.
- Trajectories of stranger fear predict individual differences in behavioral inhibition.

Introduction

Fearfulness in the presence of strangers is thought to emerge around 6 months of age (Field, 2008; Waters,

Matas & Sroufe, 1975) and increase throughout the first year of life (Emde, Gaensbauer & Harmon, 1976; Sroufe, 1977). The onset of stranger fear is believed to be adaptive, offering balance to infants' propensities for approach and exploration (Bretherton & Ainsworth, 1974) and contributing to the quality of the emerging attachment system (Ainsworth, 1973). However, extreme stranger fear is a precursor to the development of social anxiety (de Rosnay, Cooper, Tsigaras & Murray, 2006; Kagan, 2000; Kagan, Reznick & Snidman, 1987). Thus, although stranger fear has been depicted as both normative and problematic, attempts to disentangle normative from risk-related development are rare. We examined stranger fear across infancy and toddlerhood to identify normative and atypical developmental trajectories.

Individual differences in trajectories of developing stranger fear are understudied given widespread belief

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that stranger fear emerges and develops in a predictable fashion (Sroufe, 1977; Thompson & Limber, 1990). However, temperament research has shown individual differences in observed distress to a stranger to be a reliable marker for heightened behavioral inhibition, a risk factor for the development of anxiety characterized by heightened reactivity to novelty (Kagan, 2000; Kagan *et al.*, 1987). Behavioral inhibition has been linked with levels of reactivity to both social and nonsocial stimuli (Kagan, 2000; Kagan *et al.*, 1987), but has specific ties to the emergence of social anxiety by adolescence Hirshfeld-Becker, Biederman, Henin, Faraone, Davis, Harrington & Rosenbaum, 2007; Biederman, Hirshfeld-Becker, Rosenbaum, Hérot, Friedman, Snidman, Kagan & Faraone, 2001; Neal, Edelmann & Glachan, 2002; Schwartz, Snidman & Kagan, 1999). Although stranger fear and behavioral inhibition are not identical constructs, the degree of overlap in behavioral markers and outcome measures suggests that the early development of extreme stranger fear may be particularly relevant for identifying early risk for the development of anxiety problems.

Moreover, consistent with the developmental psychopathology perspective (Sroufe & Rutter, 1984), elucidating differences in developmental trajectories of stranger fear over time, rather than at a single time point, can help us to more accurately characterize the link between stranger fear and behavioral inhibition. For example, multiple studies have suggested that stable patterns of fearfulness over time may be more robust predictors of risk for anxiety than single measures. Children who remain inhibited between 21 months and 7.5 years of age had higher rates of anxiety disorders than children who were uninhibited or unstably inhibited across this period (Hirshfeld, Rosenbaum, Biederman, Bolduc, Faraone, Snidman, Reznick & Kagan, 1992). Similarly, stability in maternal-reported inhibition between 14 months and 7 years of age was associated with 3.79 times greater odds of a lifetime diagnosis of Social Anxiety Disorder (Chronus-Tuscano, Degnan, Pine, Perez-Edgar, Henderson, Diaz, Raggi & Fox, 2009).

Other work has shown that the stability of behavioral inhibition and stranger fear over time are relatively low (Perez-Edgar & Fox, 2005; Kagan & Snidman, 1999; Sroufe, 1977). Thus, one might reasonably expect to find a subset of infants high in stranger fear to exhibit decreasing levels of wariness over time, as early levels shift into the normal range. Advances in statistical techniques have enabled the examination of individual differences in developmental trajectories in other areas of research (e.g. Garstein, Bridgett, Rothbart, Robertson, Iddins, Ramsay & Schlect, 2010). Here, we aimed to elucidate individual differences in the developmental

trajectories of stranger fear during infancy and their association with behavioral inhibition.

Parasympathetic regulation as a predictor of anxiety risk

It is important not only to understand whether individual differences in stranger fear exist, but also which factors might predict such differences. One frequently studied predictor of behavioral inhibition is respiratory sinus arrhythmia (RSA; Porges, 1986, 1996). During interactions with novel adults, RSA suppression, or a decrease in RSA relative to baseline, is associated with observed levels of distress and positive affect in toddlers (Brooker & Buss, 2010; Buss, Goldsmith & Davidson, 2005). RSA is often viewed as a relatively pure index of regulation given that it facilitates recovery from increases in heart rate, such as those that occur during emotion elicitation. In these cases, greater RSA suppression is often linked with better emotional and physiological regulation. As one example of this, an infant's quick recovery from heightened heart rate is associated with regulation during a stranger interaction (Waters *et al.*, 1975). In this way, greater RSA suppression may mark infants' regulation during episodes of distress, such as during novel social interactions. In contrast, a failure to regulate cardiac reactivity has been frequently reported in behaviorally inhibited children (Kagan, Reznick, Clarke, Snidman & Garcia-Coll, 1984; Kagan, Reznick, Snidman, Gibbons & Johnson, 1988; Reznick, Kagan, Snidman, Gersten, Baak & Rosenberg, 1986). Recall that behaviorally inhibited children are high in social fear and wariness, perhaps suggesting deficits in systems of physiological regulation that impact social interaction.

It should be noted, however, that RSA suppression is not necessarily a marker that is specific to regulation of the fear response. Moreover, inconsistencies exist in the direction of the link between changes in RSA and fearfulness. Previous research has suggested that associations between RSA and fearfulness may differ depending on the incentive properties of eliciting episodes. For example, RSA suppression has been linked to aggressive behavior problems (Calkins & Dedmon, 2000), and RSA augmentation, or increases in RSA relative to baseline during some social tasks, has been linked to decreases in internalizing problems (Hastings, Nuselovici, Utendale, Coutya, McShane & Sullivan, 2008). Further, it is important that work with RSA be appropriately interpreted within the context of development (Beauchaine, 2001). Despite some directional inconsistencies, evidence supports the idea of a link of behavioral inhibition to both stranger fear and RSA. Therefore, it is possible that RSA may be associated with the developmental course

of stranger fear early in life. We conducted an exploratory test of this possibility with a subsample of participants.

Maternal contributions to the development of anxiety risk

Past work also suggests that maternal characteristics contribute to infant fearfulness. Maternal social phobia predicts increasing stranger fear between 10 and 14 months of age (Murray, de Rosnay, Pearson, Bergeron, Schofield, Royal-Lawson & Cooper, 2008) while maternal depression predicts steeper increases in fearfulness between 4 and 12 months (Garstein *et al.*, 2010). Although some of these associations involve relatively broad measures of children's fearfulness, maternal behaviors could impact stranger fear more specifically. It has been suggested, for example, that because the onset of stranger fear coincides with the development of infant tendencies to reference a parent in novel situations, parent behaviors become particularly salient cues for the development of social anxiety (Murray *et al.*, 2008). Furthermore, infants' displays of fear in response to a stranger are influenced by the presence of anxious behaviors in mothers (de Rosnay *et al.*, 2006). Even in temperamentally fearful infants, fearfulness in response to a stranger was mitigated when mothers modeled positive rather than anxious social behaviors. Thus, we examined maternal stress and negative affect as predictors of individual differences in stranger fear.

Of course, a second way that mothers may contribute to the development of stranger fear is via genetic pathways. The children of anxious parents are at increased risk for the development of anxiety problems (Mancini, Van-Ameringen, Szatmari & Fugere, 1996; Turner, Beidel & Costello, 1987). Social anxiety and social phobia are indeed heritable, with twin-based estimates of genetic influences ranging from 10% to 60% (Hettema, Prescott, Myers, Neale & Kendler, 2005; Kendler, Markowski & Prescott, 1999). Few studies have examined the heritability of stranger fear directly, though doing so may provide information about the heritability of anxiety risk prior to the onset of clinical symptoms. One exception to this general lack of emphasis on stranger fear was a study by Goldsmith and colleagues (1999), which reported that covariation among mother-reported, father-reported, and observed stranger fear in 9-month-old infants was entirely accounted for by genetic factors. It remains unknown whether developmental trajectories themselves, rather than specific behaviors, might also be heritable. However, to the extent that some trajectories of stranger fear may be more strongly linked to anxiety risk than others, it will be

valuable to identify both genetic and environmental influences on development.

Current study and hypotheses

In summary, gaps remain in our knowledge of the development of stranger fear. The ability to address these gaps is important, as doing so may help to constrain current definitions of early risk for anxiety with regard to stranger fear. Moreover, this type of work adds to our basic knowledge about how stranger fear develops during infancy, which aspects of early development influence trajectories of stranger fear, and the ways that early pathways of development relate to problematic outcomes (i.e. inhibition). We did this by (1) describing the typical development of stranger fear between 6 and 36 months of age, (2) exploring the possibility that subsets of the population deviate from the typical developmental pattern, and also exploring the degree to which different developmental trajectories were associated with (3) RSA in infancy, (4) maternal characteristics (5) and toddlers' behavioral inhibition. We also sought to gain information about the heritability of individual differences in stranger fear development by comparing rates of concordance (i.e. similarities) in trajectories of stranger fear in pairs of monozygotic and dizygotic twins.

First, we expected that stranger fear would increase during infancy and then become variable across toddlerhood. Second, we expected that a single trajectory of development in stranger fear would be inadequate to explain the observed variability over time. Drawing from limited prior research, we expected to see distinct trajectories of stranger fear including but not necessarily limited to the following: a trajectory illustrating the normative pattern of low, but increasing stranger fear over time; a trajectory following the traditional pattern of risk, with stable levels of high fear over time; and a trajectory in which stranger fear decreases over time. Third, we expected that RSA and mothers' psychological stress reactivity, well-being, and negative affect would differentiate between developmental trajectories of stranger fear. Although these analyses were largely exploratory, we hypothesized that poor RSA suppression and greater maternal stress and negativity would be associated with atypical stranger fear trajectories. Finally, we expected some trajectories, such as stable high fear, to be more closely linked with a continuous measure of behavioral inhibition than others, and thus hypothetically linked to a greater risk for anxiety later in life. Finally, we expected trajectories of stranger fear to be heritable, particularly those related to risk for social anxiety, given evidence that anxiety risk is heritable.

Method

Participants

Participants were drawn from a longitudinal twin study of emotional development (Lemery-Chalfant, Goldsmith, Schmidt, Arneson & Van Hulle, 2006). The sample was recruited from the greater Madison, Wisconsin area. Participants were recruited through a variety of methods including Wisconsin state birth records, mothers of twins clubs, television publicity, birth announcements in newspapers, doctors' offices, the Internet, and referrals from participants. Ongoing recruitment procedures allowed families to enter the study at any time prior to children reaching 36 months of age. Descriptive statistics for participant demographics are shown in Table 1. Note that some families chose not to report on race, income, or level of education. The sample includes those infants with parent-report data during at least one assessment between 6 and 36 months of age ($N = 1285$ individuals). Thirty-six percent of participants were members of a monozygotic twin pair. Thirty-five percent of participants were from same-sex twin pairs; the remaining twins were from opposite-sex twin pairs (29%).

Table 1 Sample demographics

	Mothers		Fathers	
	<i>n</i>	%	<i>n</i>	%
Race				
Caucasian	736	95.0	718	92.8
African American	13	1.7	21	2.7
Asian American	7	0.9	7	0.9
American Indian	3	0.4	2	0.3
Hispanic	11	1.4	16	2.1
Other	5	0.6	10	1.2
Education				
Grade school	1	0.1	2	0.3
Some high school	10	1.3	18	2.4
High school graduate	108	14.5	144	19.1
Some college	221	29.6	207	27.5
College graduate	234	31.4	208	27.6
Some graduate training	105	14.1	87	11.5
Graduate degree	67	9.0	88	11.6
Family income before taxes	<i>n</i>		<i>n</i>	%
\$15,000 or less	15		23	2.3
\$16,000 – \$20,000	23		55	3.5
\$21,000 – \$30,000	55		87	8.4
\$31,000 – \$40,000	87		90	13.3
\$41,000 – \$50,000	90		101	13.8
\$51,000 – \$60,000	101		281	15.5
Above \$60,000	281			43.1

Note: *n* refers to numbers of families.

Procedure

Infants visited the laboratory at 6, 12, and 36 months of age. Consistent with the aims of the parent study, assessment ages were selected to coincide with known critical periods of early emotional development. Approximately 2 weeks after the 6-month laboratory visit, a random subset of families were invited to return for the collection of psychophysiological data ($n = 124$ individuals). At each laboratory assessment, infants participated in a number of episodes designed to elicit multiple emotional responses. This study is focused on those episodes in which infants were invited to interact with a stranger. Following laboratory assessments, parents completed a packet of questionnaires and mailed them back to the laboratory. Parents also completed questionnaires via mail when children were 22 months of age.

Missing data

Out of a total of 989 families who provided data at any assessment (recall that recruitment was ongoing through 36 months), participation ranged from 252 families to 516 families participating at any individual assessment. A total of 141 families were either invited to participate but refused or agreed to participate but never returned questionnaires or attended scheduled laboratory visits. Following recruitment at 3 months of age, a total of three families had withdrawn participation from the study before the 6-month assessment, a total of 17 families had withdrawn from the study before the 12-month assessment, a total of 42 families had withdrawn before the 22-month assessment, and a total of 88 families had withdrawn before the 36-month assessment. A subset of families did not withdraw from the study but did not participate at 6 ($n = 98$ families), 12 ($n = 216$ families), 22 ($n = 299$ families), and/or 36 ($n = 346$ families) months of age.

A series of one-way ANOVAs (Bonferroni corrections) suggested that some differences existed between children in families who chose to participate versus those who did not, though these differences were generally not stable over time. Families who participated in the 6 month assessment had infants who showed less fear at 12 months than those families who began participation after the 6-month assessment ($F_{2,680} = 5.58, p < .01$). Families who participated in the 12-month assessment had mothers who reported less negative affect than mothers in families who had withdrawn from the study by this time ($F_{3,871} = 5.12, p < .01$). At 36 months, families who had withdrawn from the study had mothers who reported greater negative affect than both mothers in families who participated in the 36-month assessment and mothers in families who did not participate in the

36-month assessment (but had not withdrawn from the study; $F_{2, 871} = 9.37, p < .01$).

Roughly 55% of families who participated in the 6-month laboratory visit returned for psychophysiological assessments. Most frequently, families who did not participate felt that they were too busy to participate in all three assessments. Those who agreed to participate in the psychophysiological assessment did not significantly differ on any of the study's primary variables (all $|t|s < 1.91, ps > .05$) from those who did not participate.

Measures

Parent-reported stranger fear

Mothers and fathers completed age-appropriate temperament questionnaires for each infant during the 6- (*Infant Behavior Questionnaire*, IBQ; Rothbart, 1981), 12- (IBQ), 22- (*Toddler Behavior Assessment Questionnaire*; Goldsmith, 1996), and 36-month assessments (*Children's Behavior Questionnaire*; Rothbart, Ahadi, Hershey & Fisher, 2001).

A stranger fear scale was created for each questionnaire by selecting items that asked about infants' interactions with new people. Relevant items from each questionnaire were submitted to principal components analyses (all scales range 1–7); those with low item–total correlations and/or low factor loadings were removed.¹ Remaining items were averaged to create a score of stranger fear. Scales showed high internal consistency for both mothers and fathers (Table 2). In order to reduce the potential bias contained in single-reporter ratings, maternal and paternal reports were averaged to produce a single score at each age. Notably, maternal and paternal ratings were correlated at 6 ($r = .47, p < .01$), 12 ($r = .63, p < .01$), 22 ($r = .49, p < .01$), and 36 ($r = .59, p < .01$) months, supporting the formation of composite measures.

Observed stranger fear

During the 6- and 12-month laboratory visits, infants participated in a modified 3-minute *Stranger Approach* episode from the *Laboratory Temperament Assessment Battery* (Lab-TAB; Goldsmith & Rothbart, 1996). Infants were seated in a high chair near the center of a

¹ The stranger fear scale for each measure included the following items. Infant Behavior Questionnaire: questions 75, 76, 77, 78, and 79 (reversed). Toddler Behavior Assessment Questionnaire: questions 4, 5, 16, 41 (reversed), and 42 (reversed). Child Behavior Questionnaire: questions 23 (reversed), 37, 57 (reversed), 74, 89, 106, and 129 (reversed).

Table 2 Psychometric properties for scales of parent-reported stranger fear

Assessment age	Original measure	<i>n</i> items	α		Correlation between maternal and paternal report
			Mothers	Fathers	
6 months	IBQ	5	0.86	0.84	0.47
12 months	IBQ	5	0.90	0.89	0.63
22 months	TBAQ	5	0.80	0.76	0.49
36 months	CBQ	7	0.90	0.87	0.59

Note: IBQ: Infant Behavior Questionnaire, TBAQ: Toddler Behavior Assessment Questionnaire, CBQ: Child Behavior Questionnaire.

room into which an affectively neutral, male stranger entered. The stranger paused near the door for 10 seconds before approaching half of the distance toward the child. The stranger then paused, addressed the child, approached the rest of the distance to the child, and knelt near him/her for 2 minutes. At the end of this period, the stranger rose, retreated, and exited the room.

Intensity of facial fear was coded on a 4-point scale adapted from the *Maximally Discriminative Facial Movement Coding System* (Izard, 1979). Codes ranged from no facial region showing codable fear (0) to the presence of fear across all three regions (brow, eye, and mouth) of the face (3). Codes were assigned every 5–10 seconds for both the 6- and 12-month episodes (mean $\kappa = 0.78$).² Codes were averaged across the episode to create a score of observed fear at each age. Given that observations of stranger fear were available only for the 6- and 12-month assessments, these ratings were used to validate the latent classes that were observed in the parent report data rather than as a part of the trajectories themselves.

Behavioral inhibition

During the 36-month visit, children participated in the *Risk Room* episode (Reznick *et al.*, 1986) described in the *Preschool Lab-TAB* (Goldsmith, Reilly, Lemery, Longley & Prescott, 1999). We focused on behaviors during the first of two phases. For the first phase, the experimenter led the child into a room containing several novel toys: a canvas tunnel, a set of steps leading to a small platform above a mattress, a wooden balance beam, a carpeted incline along one side of the room, a black cardboard box with a jagged hole in it, and a large

² Coding epochs differ somewhat in length given that they are anchored to the stranger's behavior during the episode. The coding sheet, which clarifies coding intervals, is available from the authors upon request.

gorilla mask mounted on a cardboard pedestal. The experimenter then left the room and allowed the child to play freely for 5 min.³

During the first minute, the following variables were coded every 10 seconds: number of toys touched, latency to touch first toy, approach parent, and tentativeness of play. Subsequently, these variables were coded every 30 seconds (mean $\kappa = 0.87$). Number of toys touched and latency to touch first toy were scored as a count of number of toys and number of seconds, respectively. Approach parent was scored on a 4-point scale ranging from the child exploring toys without any glances or comments to his/her parent (0) to the child taking purposeful action to be within 3 feet of the parent (3). Tentativeness of play was scored on a 4-point scale ranging from the child exhibiting no hesitancy in exploring objects (0) to the child exhibiting extreme hesitancy such that s/he spent no time exploring objects (3). Scores were averaged within behavior across the episode and transformed to *z*-scores. A factor composite of inhibition to novelty during the *Risk Room* was created from these behaviors using PCA factor scores, similar to Pfeifer, Goldsmith, Davidson and Rickman (2002). The composite accounted for 73.03% of the variance in the original variables and showed high internal consistency ($\alpha = 0.88$).

Physiological measures

Cardiographs were collected using the CIC-1000TM Impedance Cardiograph, software version 7.2 (SORBA Medical Systems, 1997). Collection occurred during a baseline period (*Baby Mugs*; MVP Home Video) and during the *Stranger Approach*. Continuous, raw electrocardiography (ECG) was collected from the SORBA output system. This signal was band-pass filtered at 30 Hz and 100 Hz, amplified 20 K, and sampled in 500-ms intervals. Raw ECG signal was transformed into inter-beat intervals (IBIs) using an adjustable threshold to detect R-waves. IBIs were entered into MXedit software (Delta-Biometrics, Inc., Bethesda, MD) to identify and edit artifacts. The heart period time series was sampled in successive 500-ms intervals using a 21-point moving cubic polynomial to detrend data and a 25-point band-pass filter applied (0.24 Hz to 1.04 Hz). RSA scores reflect the natural logarithm of the variance in this frequency band. MXedit output calculates cardiac indices sequentially every 30 seconds and sums across

periods. RSA suppression was calculated by subtracting baseline values from values during the *Stranger Approach*. Note that decreasing, or more negative, numbers indicate a decrease in RSA from baseline to task, or greater RSA suppression.

Maternal characteristics

We used the *Multidimensional Personality Questionnaire* (Tellegen & Waller, 2008) to measure maternal well-being and stress reactivity at child age 22 months. Mothers rated the degree to which different statements, describing common attitudes and behaviors, were true of them. Ratings were averaged to create overall scores of well-being ($\alpha = 0.90$) and psychological reactivity to stress ($\alpha = 0.90$).

We used the *Positive and Negative Affect Scale* (PANAS; Watson, Clark & Tellegen, 1988) to measure maternal negative affect when infants were 3, 6, 9, and 12 months of age. Mothers rated the degree to which they had experienced different emotions over the course of the previous few weeks; negative emotion items were averaged to create a mean composite ($\alpha = 0.87$). A trait-level composite was created by averaging the scores across 3 to 12 months.

Results

Descriptives and first-order associations among variables

Descriptive statistics and correlations for variables are shown in Tables 3 and 4, respectively. As expected, a sample of one twin selected randomly from each pair did not differ from their co-twin on any variables. Both parent-reported (6 to 36 months of age) and observed stranger fear (6 to 12 months of age) showed moderate stability. However, stability never accounted for more than 25% of the shared variability in stranger fear across assessments, suggesting that changes in stranger fear were occurring.

Greater stranger fear was correlated with greater inhibition at 36 months of age, less RSA suppression during *Stranger Approach* at 6 months, less maternal well-being and greater maternal reactivity to psychological stress. However, these correlations were not evident at all assessments.

Normative development of stranger fear

Scores of parent-reported stranger fear were fit to a two-level linear mixed growth model (Level 1: family, Level 2:

³ The parent who had accompanied the child to the laboratory was present throughout the episode but was instructed not to interact with the child.

Table 3 Descriptive statistics for variables

	<i>n</i>	Min	Max	<i>M</i>	<i>SD</i>	<i>t</i>
6-mo Stranger Fear	489	1.00	6.50	2.92	1.15	0.23
12-mo Stranger Fear	696	1.00	7.00	4.14	1.28	-1.09
22-mo Stranger Fear	925	1.00	7.00	4.04	1.08	-0.82
36-mo Stranger Fear	818	1.00	6.86	4.22	1.14	-0.05
6-mo Facial Fear	442	0.00	3.00	0.32	0.42	-1.47
12-mo Facial Fear	681	0.00	3.00	0.40	0.43	-1.39
36-mo Behavioral Inhibition	903	-1.60	2.34	-0.01	0.84	0.35
Baseline RSA	124	1.86	5.60	3.55	0.77	-0.63
RSA Suppression	88	-2.39	2.36	0.01	0.96	1.53
Maternal Negativity	872	1.00	5.00	1.92	0.58	NA
Maternal Well-Being	826	1.50	4.00	3.14	0.46	NA
Maternal Psychological Stress Reactivity	826	1.17	3.83	2.35	0.54	NA

Note: *t* is the product of a *t*-test comparison of twins, NA = Not Applicable because variable was assessed at the parent level, RSA = Respiratory Sinus Arrhythmia. *ns* refer to numbers of individuals.

twins within families) in SAS version 9.3 (SAS Institute, 2011). Using a multilevel mixed growth model allows for the examination of continuous change over time in data that may violate assumptions of independence. Model fit was determined using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Covariance parameter estimates suggested that significant variation around the intercept ($z = 5.61, p < .01$), linear ($z = 3.14, p < .01$), and quadratic slopes ($z = 3.40, p < .01$) remained after accounting for the nesting of twins within families. Therefore, random terms, which allowed intercept, linear change, and quadratic change to vary across individuals, were included in the final model.

Normative, or typical, development included significant changes in stranger fear between 6 and 36 months of age ($F_{LIN}(1, 2282) = 206.00, p < .01; F_{QUAD}(1, 2282) =$

$115.40, p < .01; F_{CUB}(1, 2282) = 87.88, p < .01$). Follow-up contrasts comparing levels of stranger fear at adjacent assessments confirmed an increase in stranger fear between the 6- and 12-month ($F(1, 233) = 183.17, p < .01$) and 22- and 36-month assessments ($F(1, 233) = 5.47, p < .05$), but no change between the 12- and 22-month assessments ($F(1, 233) = 0.76, p > .10$).

Individual differences in stranger fear development

We tested for individual differences in trajectories of stranger fear using latent class growth analysis (LCGA) in MPlus Version 4 (Muthén & Muthén, 2006). LCGA identifies latent classes of individuals whose trajectories differ from the overall group by relaxing the assumption that all individuals are drawn from a single population (Jung & Wickrama, 2008; Muthén, 2004). Doing so allows for the presence of different groups of growth trajectories in stranger fear that vary around separate means, resulting in separate growth models for each latent class. Analyses began with a one-class solution and progressed until adding additional classes no longer improved fit over the previous model. Examination of the following fit statistics suggested that the four-class solution best fit the data: AIC, BIC, Entropy, and Parametric Bootstrapped Likelihood Ratio Test (Table 5).

Mirroring the normative overall trajectory described in the extant literature and in the sample as a whole, the two most common classes showed low levels of stranger fear at 6 months and increases in stranger fear over time (Figure 1). These two classes were differentiated by their rates of increase, with one group showing steeper (42.3%) and the other showing slower (32.9%) increases in stranger fear over time. Also present were two classes of infants who showed high levels of stranger fear at

Table 4 Intercorrelations among variables

	1	2	3	4	5	6	7	8	9	10	11
1. 6-mo Stranger Fear											
2. 12-mo Stranger Fear	0.38**										
3. 22-mo Stranger Fear	0.24**	0.50**									
4. 36-mo Stranger Fear	0.14*	0.29**	0.44**								
5. 6-mo Facial Fear	0.07	0.10 [±]	0.09	0.06							
6. 12-mo Facial Fear	-0.02	0.22**	0.09*	0.02	0.25**						
7. 36-month Inhibition	-0.02	0.07	0.09*	0.11**	0.06	0.10*					
8. Baseline RSA	-0.02	-0.23*	-0.24*	-0.10	0.26*	0.10	-0.10				
9. RSA Suppression	-0.02	-0.19	0.10	0.36**	0.04	-0.04	0.20	-0.20 [±]			
10. Maternal Negativity	0.15**	0.21**	0.07 [±]	0.03	-0.05	0.08 [±]	-0.04	-0.09	0.13		
11. Maternal Well-being	-0.06	-0.11*	-0.06	-0.03	0.08	-0.10*	0.01	-0.10	-0.21	-0.34**	
12. Maternal Stress Reactivity	0.11 [±]	0.09*	0.13**	0.02	-0.05	0.04	-0.06	0.02	0.14	0.44**	-0.50**

Note: ** $p < .01$; * $p < .05$; [±] $p < .10$.

Table 5 Fit statistics for latent class growth analysis models

<i>n</i> groups	AIC	BIC	Entropy	LRT
3	9019.05	9080.95	0.42	48.59**
4	9004.78	9082.15	0.47	20.27**
5 ^a	8995.28	9088.14	0.43	15.49**

Note: LRT = Parametric Bootstrapped Likelihood Ratio Test, ^aThe -2 Log Likelihood value for the model did not replicate, suggesting possible convergence problems, ** $p < .01$.

6 months; the first of these maintained high levels of stranger fear across assessments (11.8%), while the second showed decreases in stranger fear (12.1%), particularly between 12 and 36 months of age.

Individuals were assigned to trajectory groups based on the LCGA results. Post-hoc analyses were conducted to confirm that classes represented unique trajectories of stranger fear. A repeated-measures ANOVA was used to test the significance of group-level differences in the development of stranger fear over time. This analysis confirmed that all latent trajectories were significantly different from one another as indicated by a significant Time (6, 12, 22, and 36 months) by Class (high/steady, decreasing, steep increase, slow increase) interaction ($F(9, 690) = 15.91, p < .01$) and follow-up comparisons (all $ps < .01$). Similarly, a series of one-way ANOVAs confirmed that classes differed in stranger fear at each assessment with the exception of the decreasing class; which showed equivalent levels of stranger fear to the high/steady class at 6 months, the steep increase class at 22 months, and the slow increase class at 36 months. To provide additional validation, a one-way ANOVA showed that latent classes differed in observed stranger fear at both 6 ($F(3, 441) = 4.01, p < .01$) and 12 ($F(3, 680) = 6.96, p < .01$) months of age. Class-based differences in facial fear largely mirrored differences in parent-report

data at the first two assessments (Figure 2) although standard errors were larger for observational measures.

Heritability and trajectories of stranger fear

The pairwise concordance of trajectory group membership for monozygotic (MZ) and dizygotic (DZ) twins was calculated as the ratio of concordant pairs to the total number of pairs for each trajectory group. Concordance, then, reflects 'matches' between co-twins on patterns of stranger fear development while discordance reflects different patterns of development for co-twins. This analysis revealed that concordance was greater in MZ relative to DZ twins in all of the trajectory classes. This suggests heritability in trajectories of stranger fear, given that MZ twins are more genetically similar than DZ twins. As shown in Table 6, this heritability denotes an increased relative risk for siblings of high-risk twins. For example, in the absence of any familial effects, the base rate suggests that there would be an approximate concordance rate of 1% for the high/steady class. Instead, concordance rates for MZ and DZ twins are 30% and 10%, respectively. This difference means that if an individual shares both half of his or her genes and a rearing environment with a co-twin who falls into the high/steady stranger fear group, then that individual is 10 times more likely to also fall into the high/steady stranger fear group than someone whose co-twin is randomly selected. The difference between MZ and DZ twin concordance rates suggests that an additional 50% gene similarity reflects threefold / increase in relative risk for membership in the high/steady fear group.

RSA and trajectories of stranger fear

Two multinomial logistic regressions tested whether class membership was predicted by 6-month baseline RSA or

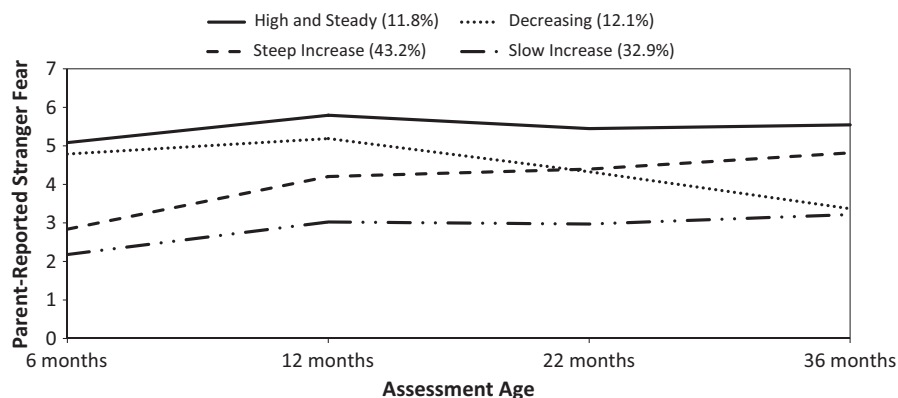


Figure 1 Observed trajectories of stranger fear from 6 to 36 months by latent class. Note: Percentages indicate the proportion of individuals included in each class.

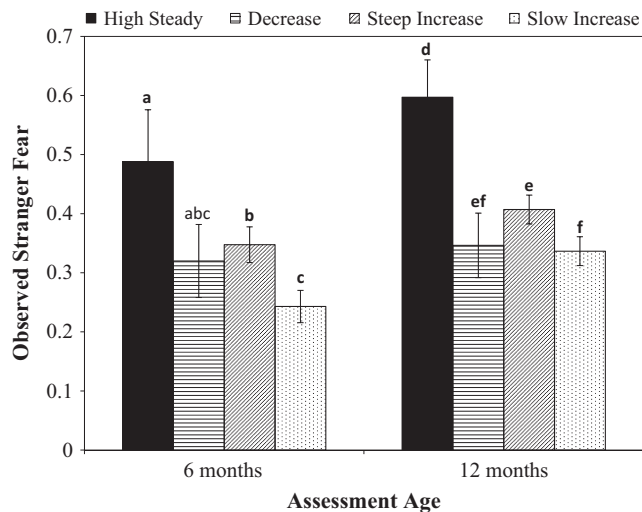


Figure 2 Class differences in observed stranger fear at 6 and 12 months of age. Notes: Classes with different letters are significantly different from one another. All differences are significant at $p < .05$ except for the difference between high/steady and steep increase at 6 months and the difference between steep increase and slow increase at 12 months, where $p < .10$. Bolded values survive Bonferroni correction at minimum of $p < .10$.

Table 6 Pairwise concordance rates for trajectories of stranger fear

	MZ concordance	DZ concordance
High/Steady	30.00%	10.39%
Decreasing	33.33%	6.25%
Steep Increase	54.30%	40.07%
Slow Increase	55.34%	28.71%

Note: Percentages indicate the proportion of individuals included in each class.

RSA suppression during *Stranger Approach* (Figure 3). Multinomial logistic regressions were selected based on the categorical outcome measure (i.e. group membership). The slow increase class served as the referent group for parameter estimates given that it (a) was closely aligned with the typical developmental trajectory of stranger fear for the sample as a whole and as described by previous research, (b) was present in high proportion in this sample, and (c) was related to normative (i.e. low fear, low inhibition) outcomes. Baseline RSA was not associated with class membership ($\chi^2(3) = 2.28, p > .10$). In contrast, 6-month RSA suppression significantly predicted class membership ($\chi^2(3) = 12.15, p < .01$). As infants showed less RSA suppression during the 6-month *Stranger Approach*, they

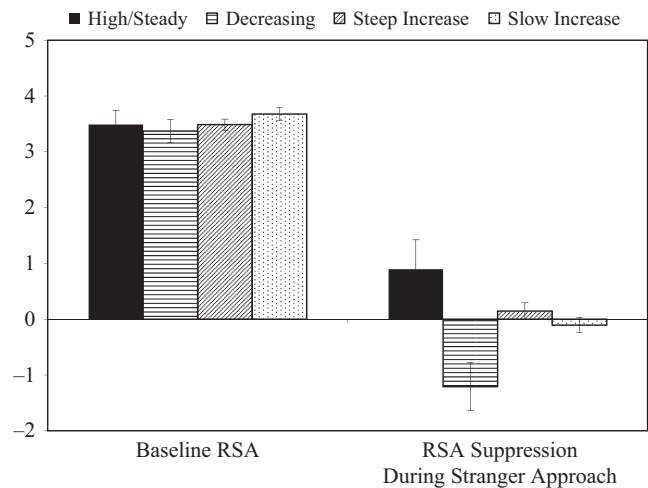


Figure 3 Class means for 6-month RSA.

became more than three times as likely to be in the high/steady class than in the slow/steady class ($OR = 3.52, 95\% CI = 1.02-12.09, p < .05$). In addition, infants with greater suppression were slightly more likely to be in the decreasing class than in the slow increase class ($OR = 0.25, 95\% CI = 0.07 - 0.91, p < .05$). These associations remained significant when baseline RSA was included in the model ($\chi^2(3) = 12.36, p < .01$).

Maternal characteristics and trajectories of stranger fear

A series of one-way ANOVAs tested whether class membership was related to maternal characteristics (i.e. negative affect, well-being, and stress reactivity; Figure 4). Note that the directionality of this analysis is somewhat arbitrary given that maternal characteristics were quantified as composites across time. Well-being did not differ among the classes ($F(3, 825) = 1.93, p > .10$). However, self-reported stress reactivity ($F(3, 825) = 3.62, p < .05$) and maternal negative affect ($F(3, 871) = 5.32, p < .01$) differed among the classes. Post-hoc comparisons revealed that mothers of infants in the high/steady class reported greater stress reactivity than all other classes. Post-hoc comparisons also showed that mothers of high/steady infants reported greater negative affect than mothers of infants in the steep or slow increase classes. In addition, mothers of infants in the decreasing class reported greater negative affect than those in the slow increase class.

Given class-related differences related to psychological stress reactivity, a construct related to anxiety, but no class-related differences related to well-being, a construct associated with symptoms of depression, an anxiety-specific composite was created from the PANAS

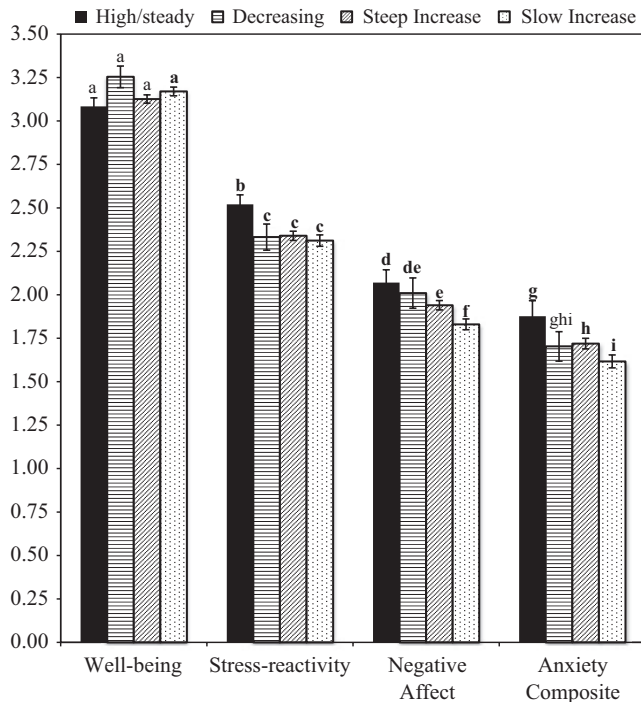


Figure 4 Class means for maternal characteristics. Notes: Classes with different letters are significantly different from one another. All differences are significant at $p < .05$. Bolded values survive Bonferroni correction at minimum of $p < .10$.

negative affect scale for comparison.⁴ Mothers of infants in the high/steady class reported greater anxiety-specific negative affect than mothers of infants in both the steep and slow increase classes ($F(3, 871) = 3.91, p < .01$). Furthermore, mothers of infants in the steep increase class reported significantly more anxiety-specific negative affect than those in the slow increase class.

Trajectories of stranger fear and behavioral inhibition

Finally, a one-way ANOVA was conducted to test whether classes differed in behavioral inhibition at 36 months of age. This analysis was significant, suggesting that class differences in trajectories of stranger fear predicted 36-month observed inhibition ($F(3, 902) = 3.00, p < .05$). Post-hoc pairwise comparisons revealed that inhibition was greater in both the high/steady and steep increase classes relative to the slow increase class (Figure 5).

⁴ This composite was similar to the overall PANAS negative affect measure in that it included all assessments, but differed in that it was an average composite of only the following four items: 7 (scared), 15 (nervous), 18 (jittery), and 20 (afraid). Across assessments, reliability for this scale ranged from $\alpha = 0.79$ to $\alpha = 0.86$.

Discussion

Results were largely aligned with our hypotheses. First, a trajectory of stranger fear was elucidated that was consistent with previous work describing the normative development of stranger fear in infancy. In line with the extant literature, stranger fear in the slow increase group rose steadily early in infancy and began to stabilize in the second year of life. This pattern of development was 'low risk' in that it was associated with relatively low levels of observed stranger fear and inhibition. Notably, however, individual variation in levels of stranger fear and trajectories of stranger fear development was present throughout infancy and toddlerhood. Individual differences in trajectories of stranger fear were associated with early physiological regulation, maternal characteristics, and behavioral inhibition.

Although the typical developmental pattern of stranger fear was aligned with hypotheses, individual variation around group means was significant as early as 6 months of age, well before stranger fear is believed to peak. Perhaps not surprisingly, latent class growth curve models suggested notable heterogeneity in the development of stranger fear across infancy and toddlerhood. Four distinct trajectories of change in stranger fear from 6 to 36 months of age were observed. Two class-based trajectories accounted for patterns of change in the majority of infants (76.1%) and largely resembled the pattern of normative development described by previous work. These two classes (steep and slow increasing) differed in how rapidly stranger fear increased over time, resulting in different levels of stranger fear at 36 months of age.

Two less-normative trajectories, high/steady and decreasing stranger fear, were also identified. These

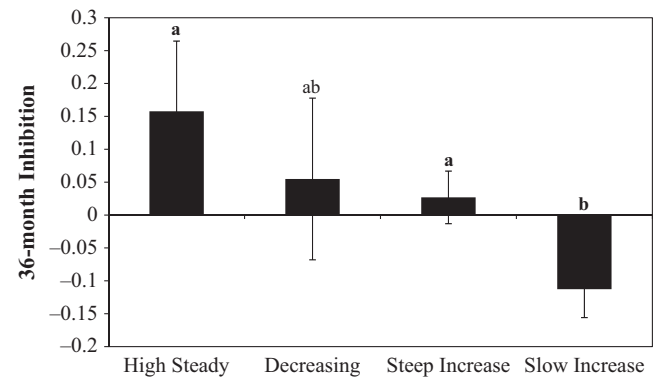


Figure 5 Class differences in 36-month inhibition. Notes: Classes with different letters are significantly different from one another. All differences are significant at $p < .05$. Bolded values survive Bonferroni correction at minimum of $p < .10$.

classes both included infants with high levels of stranger fear at 6 months, but who differed in subsequent development. Parent-reported stranger fear remained high for high/steady infants but declined dramatically for infants in the decreasing class. In fact, infants in the decreasing and slow increasing classes were reported as having the lowest levels of stranger fear at the 36-month assessment, further underscoring the notion that developmental trajectories of stranger fear are heterogeneous.

Differences in stranger fear development were linked to observed behavioral inhibition, a known risk factor for anxiety (Biederman *et al.*, 2001). Infants with high/steady stranger fear displayed more observed inhibition at 36 months than infants showing slow or steep increases in stranger fear over time. The high/steady trajectory likely overlaps with Kagan's extreme groups of inhibited toddlers. However, the use of the trajectory-based classification procedure extends traditional methods by including information about the stability of fearfulness, which may account for the link between early inhibition and anxiety (Hirshfeld *et al.*, 1992).

Unfortunately, large standard errors around the means for behavioral inhibition and observed stranger fear made it difficult to distinguish the decreasing class from other classes with regard to these outcomes. It is possible that a history of high fearfulness in infancy contributes to a risk for negative outcomes, but that maximum risk is associated with the maintenance of fearfulness over time. This idea is consistent with work in the behavioral inhibition literature, in which children with high levels of fearfulness are at increased risk for a variety of maladaptive outcomes (Biederman *et al.*, 2001; Hirshfeld-Becker *et al.*, 2007; Neal *et al.*, 2002; Schwartz *et al.*, 1999), but greater risk is associated with stably high levels of fear over time (Chronus-Tuscano *et al.*, 2009; Hirshfeld *et al.*, 1992). Mean levels of inhibition observed in the current study suggest that some level of risk may be maintained for infants in the decreasing group, although we again note that this group was not statistically distinguished from others.

Though infrequently discussed, existing literature suggests that developmental decreases in fearfulness during childhood are not uncommon. Stability estimates for stranger fear and inhibition typically fall in the low to moderate range, with a relatively high proportion of children moving from inhibited to noninhibited classifications (Perez-Edgar & Fox, 2005; Kagan & Snidman, 1999; Sroufe, 1977). Kagan (1994) has suggested that different types of fear may exist within infants who are classified as inhibited early in life which may be uniquely related (or unrelated) to risk for disorder and may account for individual differences in developmental

change. Still other work suggests that environmental factors (e.g. maternal behaviors: Crockenberg & Leerkes, 2004; Hane, Cheah, Rubin & Fox, 2008) can foster decreases in observed fearful behaviors over time, though the underlying propensity for fearfulness may remain unchanged. An important caveat to this, of course, is that declines in fearfulness are not normative during the period of infancy investigated here. In fact, increases in fearfulness early in life are thought to contribute to infant safety and the attachment relationship as infants begin to locomote. It may be the case, as we discuss later, that deviation from typical developmental patterns represents a facet of developmental risk. Thus, although it is notable that this study found heterogeneous patterns of stranger fear development during infancy, individual patterns of change in fear, including declines in fearfulness over time, should be more fully characterized alongside developmental outcomes in future investigations.

Trajectories of stranger fear were also associated with RSA suppression during an interaction with a stranger at 6 months of age. Less RSA suppression predicted an increased likelihood of belonging to the high/steady trajectory rather than the more normative trajectories. This finding aligns with previous work linking poor cardiac regulation with indices of anxiety risk in early infancy, namely high reactivity (Calkins & Fox, 1992; Fox, 1989; Stifter & Fox, 1990).

An examination of twin concordance rates suggested high levels of heritability for trajectories of stranger fear. DZ concordance rates showed that sharing a family environment and having an average of 50% of genetic overlap with a co-twin in the high/steady class increased roughly tenfold the likelihood that an infant would show a high/steady trajectory of stranger fear. MZ concordance rates suggested that sharing a family environment and having 100% genetic overlap with a co-twin in the high/steady class increased roughly thirtyfold the likelihood that an infant would show a high/steady trajectory of stranger fear. As previously stated, this difference in concordance rates between DZ and MZ twins suggests that sharing an additional 50% of genetic overlap triples the relative risk of being a member of the high/steady class.

Finally, consistent with expectations, maternal characteristics were also associated with trajectories of stranger fear development. No class-related differences existed based on maternal reports of well-being, an index linked to the development of depression (Krueger, 1999). Previous work has suggested that children's behavioral inhibition is associated with diagnoses of maternal unipolar depression (Kochanska, 1991), but we did not study psychiatric diagnoses.

Our key finding with regard to maternal characteristics was that mothers who reported greater stress reactivity were more likely to have infants with chronically high levels of stranger fear than infants who followed any other trajectory of stranger fear development. This pattern largely reflected the effects of anxiety-related negative affect which distinguished infants with steeply increasing stranger fear from those infants that increased steadily. Moreover, these associations with developmental trajectories parallel those seen for inhibition. At least one study has shown inhibition to be linked to maternal anxiety, regardless of whether depression symptoms were also present (Biederman *et al.*, 2001). Thus, relative to symptoms of maternal depression, such as negative affect, facts of maternal anxiety may more robustly predict anxiety risk in children. It is important to note that given the timing of maternal assessments, it is possible that this association is bi-directional. There is, in fact, evidence that temperamental characteristics in children, including fearfulness, can evoke behaviors (Crockenberg, 1981; Crockenberg & McCluskey, 1986) and symptoms in parents over time (Brooker, Neiderhiser, Ganiban, Leve, Shaw & Reiss, 2012).

Also of note, it is interesting that mothers of children in the decreasing class reported greater negative affect than mothers of children whose fear increased slowly over this period. One explanation for this lies in the argument for reciprocal, bi-directional influences stated above. That is, differences between mothers may reflect a lagged association with the difficulty of raising a fearful infant. Thus, it would be interesting to know whether heightened levels of maternal negative affect continue to be associated with the decreasing class over time.

A second possible explanation is that a pattern of decreasing fear between 6 and 36 months of age reflects some level of heightened risk associated with atypical versus typical development of stranger fear. This notion has been suggested in other research (Hirshfeld *et al.*, 1992) but has largely focused on stable, high levels of fear in infancy. Because additional patterns of fear development have not previously been uncovered, it is difficult to fully understand the risk associated with atypical development versus risk associated specifically with stable, high fearfulness and the degree to which such development may be related to maternal negative affect. However, according to the developmental psychopathology perspective, it is not impossible that any deviation from a normative developmental course might carry with it some level of risk (Sroufe & Rutter, 1984) which may, in turn, be linked to high levels of negative affect in mothers. Clearly, disentangling these associations is a ripe area for future research.

Limitations

This study is not without limitations. We recognize that concerns exist that twin samples may not represent the general population on one or more subsets of behavior that may bias results in some systematic way. In fact, there are differences between twins and nontwins early in life in factors such as gestational age at birth, birth weight, and rate of language acquisition (see Plomin, DeFries, McClearn & McGuffin, 2008, for review). However, many of these differences decline and disappear by the early school years. Research has now shown that results from twin studies largely generalize to nontwins (e.g. Andrew, Hart, Snieder, de Lange, Spector & MacGregor, 2001), including on measures relevant to the current work, such as temperament (Goldsmith & Campos, 1990), personality (Johnson, Krueger, Bouchard & McGue, 2002) or psychopathology (Christensen, Vaupel, Holm & Yashlin, 1995). Second, unequal numbers of infants in trajectory-related classes alter the power to detect significant differences across these groups. Namely, the smaller numbers of infants in the less-normative groups, and the decreasing group in particular, made for less robust estimations of means, larger standard errors, and a decreased likelihood that mean-level differences would be detected. Third, clinical assessments of parents and children are unavailable for our sample. Thus, although associations with anxiety risk can be tested, the degree to which any trajectory is associated with a later anxiety diagnosis is unknown. Fourth, the continuous measure of inhibition used here is operationally distinct from – yet conceptually similar to – the extreme-groups approach used by Kagan (1994) and colleagues; this difference somewhat limits comparisons across studies. Finally, participants from the current study largely come from middle-class, Caucasian families. Thus the degree to which these results are representative of the population at large may be limited. Future work in samples that include a greater degree of racial, ethnic, and socioeconomic diversity is needed.

Conclusions

The current study contributes to the existing literature in a number of important ways. First, we used a person-centered approach to illustrate a pattern of stranger fear between 6 and 36 months of age that replicates previous work on the typical development of stranger fear. To our knowledge, this is the largest longitudinal examination to date of stranger fear development in infancy. Second, we showed significant individual differences in stranger fear at 6 months of age and across early infancy and

toddlerhood; differences were validated by observations of fear and behavioral inhibition. Third, we showed that certain patterns of stranger fear development, such as chronically high levels of stranger fear or sharply increasing levels of stranger fear over time, may be linked to greater risk for anxiety early in life. Fourth, individual differences in trajectories of stranger fear were predicted by RSA suppression at 6 months of age. Finally, we showed that the developmental course of stranger fear during infancy was associated with maternal characteristics and appeared to be most closely linked to anxiety-related characteristics in mothers. This implication of heritability was underscored by differences in concordance rates for trajectory membership in MZ and DZ twins. Although replication is needed, maternal anxiety and infant physiological regulation appeared to impact individual differences in the developmental course of stranger fear and associated risk for anxiety problems later in life.

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References

- Ainsworth, M. (1973). The development of infant–mother attachment. In B. Caldwell & H. Ricciuti (Eds.), *Review of child development research* (Vol 3, pp. 1–94). Chicago, IL: University of Chicago Press.
- Andrew, T., Hart, D.J., Snieder, H., de Lange, M., Spector, T.D., & MacGregor, A.J. (2001). Are twins and singletons comparable? A study of disease-related and lifestyle characteristics in adult women. *Twin Research*, **4**, 464–477.
- Beauchiane, T. (2001). Vagal tone, development, and Gray's motivational theory: toward an integrated model of autonomic nervous system functioning in psychopathology. *Development and Psychopathology*, **13**, 183–214.
- Biederman, J., Hirshfeld-Becker, D.R., Rosenbaum, J.F., Hérot, C., Friedman, D., Snidman, N., Kagan, J., & Faraone, S.V. (2001). Further evidence of association between behavioral inhibition and social anxiety in children. *American Journal of Psychiatry*, **158**, 1673–1679.
- Bretherton, I., & Ainsworth, M. (1974). Responses of one-year-olds to a stranger in a strange situation. In M. Lewis & L. Rosenblum (Eds.), *The origins of fear: The origins of behavior* (Vol. 2, pp. 131–164). New York: Wiley.
- Brooker, R.J., & Buss, K.A. (2010). Dynamic measures of RSA predict distress and regulation in toddlers. *Developmental Psychobiology*, **52**, 372–382.
- Brooker, R.J., Neiderhiser, J.M., Ganiban, J.M., Leve, L.D., Shaw, D.S., & Reiss, D. (2012). Difficult temperament in infancy evokes changes in parent anxiety symptoms over time. Paper presented at the biennial meeting of the International Society on Infant Studies, Minneapolis, MN.
- Buss, K.A., Goldsmith, H.H., & Davidson, R.J. (2005). Cardiac reactivity is associated with changes in negative emotion in 24-month-olds. *Developmental Psychobiology*, **46**, 118–132.
- Calkins, S.D., & Dedmon, S.A. (2000). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology*, **28**, 103–118.
- Calkins, S.D., & Fox, N.A. (1992). The relations among infant temperament, security of attachment, and behavioral inhibition at twenty-four months. *Child Development*, **63**, 1456–1472.
- Christensen, K., Vaupel, J.W., Holm, N.V., & Yashlin, A.I. (1995). Mortality among twins after age 6: foetal origins hypothesis versus twin method. *British Medical Journal*, **310**, 432–436.
- Chronus-Tuscano, A., Degnan, K.A., Pine, D.S., Perez-Edgar, K., Henderson, H.A., Diaz, Y., Raggi, V.L., & Fox, N.A. (2009). Stable early maternal report of behavioral inhibition predicts lifetime social anxiety disorder in adolescence. *Journal of the American Academy of Child and Adolescent Psychiatry*, **48**, 928–935.
- Crockenberg, S.B. (1981). Infant irritability, mother responsiveness, and social support influences on the security of infant–mother attachment. *Child Development*, **52**, 857–865.
- Crockenberg, S.C., & Leerkes, E.M. (2004). Infant and maternal behaviors regulate infant reactivity to novelty at 6 months. *Developmental Psychology*, **40**, 1123–1132.
- Crockenberg, S., & McCluskey, K. (1986). Change in maternal behavior during the baby's first year of life. *Child Development*, **57**, 746–753.
- De Rosnay, M., Cooper, P.J., Tsigaras, N., & Murray, L. (2006). Transmission of social anxiety from mother to infant: an experimental study using a social referencing paradigm. *Behaviour Research and Therapy*, **44**, 1165–1175.
- Emde, R., Gaensbauer, T., & Harmon, R. (1976). *Emotional expression in infancy: A biobehavioral study*. New York: International University Press.
- Field, T. (2008). Problems in infancy. In M. Hersen & A.M. Gross (Eds.), *Handbook of clinical Psychology, Vol. 2: Children and adolescents* (pp. 966–1011). Hoboken, NJ: John Wiley & Sons.
- Fox, N.A. (1989). Psychophysiological correlates of emotional reactivity during the first year of life. *Developmental Psychology*, **25**, 364–372.

- Garstein, M.A., Bridgett, D.J., Rothbart, M.K., Robertson, C., Iddins, E., Ramsay, K., & Schlect, S. (2010). A latent growth examination of fear development in infancy: contributions of maternal depression and the risk for toddler anxiety. *Developmental Psychology*, **46**, 651–668.
- Goldsmith, H.H. (1996). Studying temperament via construction of the Toddler Behavior Assessment Questionnaire. *Child Development*, **67**, 218–235.
- Goldsmith, H.H., & Campos, J.J. (1990). The structure of temperamental fear and pleasure in infants: a psychometric perspective. *Child Development*, **61**, 1944–1964.
- Goldsmith, H.H., Lemery, K.S., Buss, K.A., & Campos, J.J. (1999a). Genetic analyses of focal aspects of infant temperament. *Developmental Psychology*, **35**, 972–985.
- Goldsmith, H.H., Reilly, J., Lemery, K.S., Longley, S., & Prescott, A. (1999b). *Laboratory Temperament Assessment Battery: Preschool Version (version 1.0, Technical Report)*. Department of Psychology, University of Wisconsin, Madison, WI.
- Goldsmith, H.H., & Rothbart, M.K. (1996). *The Laboratory Temperament Assessment Battery: Locomotor Version (version 3.00, Technical manual)*. Department of Psychology, University of Wisconsin, Madison, WI.
- Hane, A.A., Cheah, C., Rubin, K.H., & Fox, N.A. (2008). The role of maternal behavior in the relation between shyness and social reticence in early childhood and social withdrawal in childhood. *Social Development*, **16**, 795–811.
- Hastings, P.D., Nuselovici, J.N., Utendale, W.T., Coutya, J., McShane, K.E., & Sullivan, C. (2008). Applying the polyvagal theory to children's emotion regulation: social context, socialization, and adjustment. *Biological Psychology*, **79**, 299–306.
- Hettema, J.M., Prescott, C.A., Myers, J.M., Neale, M.C., & Kendler, K.S. (2005). The structure of genetic and environmental risk factors for anxiety disorders in men and women. *Archives of General Psychiatry*, **62**, 182–189.
- Hirshfeld, D.R., Rosenbaum, J.F., Biederman, J., Bolduc, E.A., Faraone, S.V., Snidman, N., Reznick, J.S., & Kagan, J. (1992). Stable behavioral inhibition and its association with anxiety disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, **31**, 103–111.
- Hirshfeld-Becker, D.R., Biederman, J., Henin, A., Faraone, S.V., Davis, S., Harrington, K., & Rosenbaum, J.F. (2007). Behavioral inhibition in preschool children at risk is a specific predictor of middle childhood social anxiety: a five-year follow-up. *Journal of Developmental and Behavioral Pediatrics*, **28**, 225–233.
- Izard, C.E. (1979). *The maximally discriminative facial action coding system*. Newark, DL: University of Delaware Press.
- Johnson, W., Krueger, R.F., Bouchard, T.J., Jr, & McGue, M. (2002). The personalities of twins: just ordinary folks. *Twin Research*, **5**, 125–131.
- Jung, T., & Wickrama, K.A.S. (2008). An introduction to latent class growth analysis and growth mixture modeling. *Social and Personality Psychology Compass*, **2** (1), 302–317.
- Kagan, J. (1994). *The nature of the child*. New York: Basic Books.
- Kagan, J. (2000). Inhibited and uninhibited temperaments: recent developments. In W.R. Crozier (Ed.), *Shyness: Development, consolidation and change* (pp. 22–29). London: Routledge.
- Kagan, J., Reznick, J.S., Clarke, C., Snidman, N., & Garcia-Coll, C. (1984). Behavioral inhibition to the unfamiliar. *Child Development*, **55**, 2212–2225.
- Kagan, J., Reznick, J.S., & Snidman, N. (1987). The physiology and psychology of behavioral inhibition in children. *Child Development*, **69**, 162–169.
- Kagan, J., Reznick, J.S., Snidman, N., Gibbons, J., & Johnson, M.O. (1988). Childhood derivatives of inhibition and lack of inhibition to the unfamiliar. *Child Development*, **59**, 1580–1589.
- Kagan, J., & Snidman, N. (1999). Early childhood predictors of adult anxiety disorders. *Society of Biological Psychiatry*, **46**, 1536–1541.
- Kendler, K.S., Markowski, L.M., & Prescott, C.A. (1999). Fears and phobias: reliability and heritability. *Psychological Medicine*, **29**, 539–553.
- Kochanska, G. (1991). Patterns of inhibition to the unfamiliar in children of normal and affectively ill mothers. *Child Development*, **62**, 250–263.
- Krueger, R.F. (1999). Personality traits in late adolescence predict mental disorders in early adulthood: a prospective-epidemiological study. *Journal of Personality*, **67**, 39–65.
- Lemery-Chalfant, K., Goldsmith, H.H., Schmidt, N.L., Arneson, C.L., & Van Hulle, C.A. (2006). Wisconsin twin panel: current directions and findings. *Twin Research and Human Genetics*, **9**, 1030–1037.
- Mancini, C., Van-Ameringen, M., Szatmari, P., & Fugere, C. (1996). A high-risk pilot study of the children of adults with social phobia. *Journal of the American Academy of Child and Adolescent Psychiatry*, **35**, 1511–1517.
- Murray, L., de Rosnay, M., Pearson, J., Bergeron, C., Schofield, E., Royal-Lawson, M., & Cooper, P.J. (2008a). Intergenerational transmission of maternal social anxiety: the role of social referencing processes in infancy. *Child Development*, **79**, 1049–1064.
- Murray, L., de Rosnay, M., Pearson, J., Bergeron, C., Schofield, E., Royal-Lawson, M., & Cooper, P.J. (2008b). Intergenerational transmission of social anxiety: the role of social referencing processes in infancy. *Child Development*, **79**, 1049–1064.
- Muthén, B. (2004). Latent variable analysis: growth mixture modeling and related techniques for longitudinal data. In D. Kaplan (Ed.), *Handbook of quantitative methodology for the social sciences* (pp. 345–368). Newbury Park, CA: Sage Publications.
- Muthén, L.K., & Muthén, B.O. (1998–2011). *Mplus user's guide*. Los Angeles, CA: Muthén & Muthén.
- Neal, J.A., Edelmann, R.J., & Glachan, M. (2002). Behavioural inhibition and symptoms of anxiety and depression: is there a specific relationship with social phobia? *British Journal of Clinical Psychology*, **41**, 361–374.

- Perez-Edgar, K., & Fox, N.A. (2005). Temperament and anxiety disorders. *Child and Adolescent Psychiatric Clinics of North America*, **14**, 681–706.
- Pfeifer, M., Goldsmith, H.H., Davidson, R.J., & Rickman, M. (2002). Continuity and change in inhibited and uninhibited children. *Child Development*, **73**, 1474–1485.
- Plomin, R., DeFries, J.C., McClearn, G.E., & McGuffin, P. (2008). *Behavioral genetics* (5th edn.). New York: Worth Publishers.
- Porges, S.W. (1986). Respiratory sinus arrhythmia: physiological basis, quantitative methods, and clinical implications. In P. Grossman, K. Janssen & D. Vaitl (Eds.), *Cardiac respiratory and cardiosomatic psychophysiology* (pp. 101–115). New York: Plenum Press.
- Porges, S.W. (1996). Physiological regulation in high-risk infants: a model for assessment and potential intervention. *Development and Psychopathology*, **8**, 43–58.
- Porges, S.W., & Bohrer, R.E. (1990). The analysis of periodic processes in psychophysiological research. Principles of psychophysiology: physical, social, and inferential elements. In J.T. Cacioppo & L.G. Tassinary (Eds.), *Principles of psychophysiology: Physical, social and inferential elements*, (pp. 708–753). New York: Cambridge University Press.
- Reznick, J.S., Kagan, J., Snidman, N., Gersten, M., Baak, K., & Rosenberg, A. (1986). Inhibited and uninhibited children: a follow-up study. *Child Development*, **57**, 660–680.
- Rothbart, M.K. (1981). Measurement of temperament in infancy. *Child Development*, **52**, 569–578.
- Rothbart, M.K., Ahadi, S.A., Hershey, K.L., & Fisher, P. (2001). Investigations of temperament at 3–7 years: the Children's Behavior Questionnaire. *Child Development*, **72**, 1394–1408.
- Schwartz, C.E., Snidman, N., & Kagan, J. (1999). Adolescent social anxiety as an outcome of inhibited temperament in childhood. *Journal of the American Academy of Child and Adolescent Psychiatry*, **38**, 1008–1015.
- Sroufe, L.A. (1977). Wariness of strangers and the study of infant development. *Child Development*, **48**, 731–746.
- Sroufe, L.A., & Rutter, M. (1984). The domain of developmental psychopathology. *Child Development*, **55**, 17–29.
- Stifter, C.D., & Fox, N.A. (1990). Infant reactivity: physiological correlates of newborn and 5-month temperament. *Developmental Psychology*, **26**, 582–588.
- Tellegen, A., & Waller, N.G. (2008). Exploring personality through test construction: development of the Multidimensional Personality Questionnaire. In G.J. Boyle, G. Matthews, & D.H. Saklofske (Eds.), *Handbook of personality theory and testing: Personality measurement and assessment* (Vol. II, pp. 261–292). London: Sage.
- Thompson, R.A., & Limber, S.P. (1990). 'Social anxiety' in infancy. In H. Leitenberg (Ed.), *Handbook of social and evaluation anxiety* (pp. 85–137). New York: Plenum Press.
- Turner, S.M., Beidel, D.C., & Costello, A. (1987). Psychopathology in the offspring of anxiety disorder patients. *Journal of Consulting and Clinical Psychology*, **55**, 229–235.
- Waters, E., Matas, L., & Sroufe, L.A. (1975). Infants' reactions to an approaching stranger: description, validation, and functional significance of wariness. *Child Development*, **46**, 348–356.
- Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, **54** (6), 1063–1070.

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