CHILD DEVELOPMENT

Child Development, November 2017, Volume 90, Number 4, Pages 1254–1271

Attachment Security Priming Decreases Children's Physiological Response to Threat

Brandi Stupica
Alma College

Bonnie E. Brett
University of Maryland

Susan S. Woodhouse
Lehigh University

Jude Cassidy
University of Maryland

Ninety 6- and 7-year-olds (49.3% White, mostly middle class) from greater Washington, DC were randomly assigned to a subliminal priming condition (secure, happy, or neutral) to determine if attachment security priming decreases physiological, expressive, and self-reported fear reactions to threatening stimuli. Dispositional attachment security was also assessed. Secure priming and attachment security each decreased electrodermal reactivity, increased vagal augmentation, and decreased fearful facial expressions compared to control conditions. Examination of a statistical interaction between security priming and child attachment indicated that, although secure children had increased vagal augmentation and fewer fearful expressions than insecure children, the effects of priming were constant across secure and insecure children. There were no priming or attachment effects associated with children's self-reported fear.

The biologically based attachment behavioral system is thought to regulate responses to threat such that when a threat is detected the attachment system is activated (Bowlby, 1969/1982, 1973). The activation of the attachment system leads individuals to seek proximity to their attachment figures—a linkage thought to result from evolutionary advantages associated with protection from potential dangers. Gaining proximity to one's attachment figures thus reduces activation of the fear/wariness behavioral system and related fear behaviors. Although Bowlby's theory regarding attachment and reactions to threat are stated at the behavioral level, it can easily be assumed that this theory should extend to physiological reactions to threat as well. Thus, it can be expected that if proximity to an attachment figure is achieved, the physiological threat response is attenuated. Thus, confidence that an attachment figure is available and responsive when needed (i.e., attachment security) is likely an important factor in the activation/deactivation of the physiological threat response such that attachment security can be thought to decrease physiological reactivity to threat.

Consistent with theory, attachment security is linked to less fear in preschoolers (Kochanska, 2001; Stevenson-Hinde & Shouldice, 1990), children (Borelli, Crowley, David, Sbarra, Anderson, & Mayes, 2010; Granot, & Mayseless, 2001), and adolescents (Duchesne, Ratelle, Poitras, & Drouin, 2009). Physiological theory and related research have bolstered this claim that security attenuates fear. Specifically, researchers have used electrodermal activity (EDA) as a marker of sympathetic nervous system (SNS) arousal, which indicates the degree to which one's "fight or flight" response is activated. For example, and most relevant to the present study, decreased SNS arousal (or a decreased "fight or flight" response) assessed via EDA has been found to characterize more secure children in response to fear-inducing film clips (Gilissen, Bakermans-Kranenburg, van IJzendoorn, & Linting, 2008; Gilissen, Bakermans-Kranenburg, van IJzendoorn, & van der Veer, 2008).

Similarly, security has been empirically linked to another aspect of autonomic functioning—parasympathetic nervous system (PNS) activation (e.g., Hill-Soderlund et al., 2008; Paret, Bailey, Roche, Bureau, & Moran, 2015; Smith, Woodhouse, Clark, &

Correspondence concerning this article should be addressed to Brandi Stupica, Psychology Department, Alma College, 614 W. Superior St., Alma, MI 48801. Electronic mail may be sent to stupicabs@alma.edu.

 0009-3920/2017/9004-0017
DOI: 10.1111/cdev.13009

Skowron, 2016). The PNS promotes rest, relaxation, and vegetative functions. The PNS, via the Xth cranial nerve, or *vagus*, enervates and regulates the heart, serving as a "vagal brake" on the heart's pacemaker, slowing the heart when the PNS is activated. Porges' (1995, 2007) polyvagal theory posits that the ventral vagal complex, which allows for PNS control of the heart, mediates engagement with the environment. When one must attend to an environmental challenge, the PNS withdraws its inhibitory control of the heart (i.e., respiratory sinus arrhythmia [RSA] goes down as the vagal brake is lifted) to allow active engagement with the stressor or to prepare an SNS response, which can then exert excitatory effects unopposed. When the environmental challenge is gone, the vagal brake can be reapplied to allow for relaxation and a return to homeostasis (i.e., RSA increases). Meta-analysis shows that increases in RSA are associated with pleasurable, relaxing conditions, whereas exposure to threats or environmental challenges is associated with reductions in RSA (Graziano & Derefinko, 2013).

Attachment-related differences in patterns of RSA withdrawal have been observed. For example, Hill-Soderlund et al. (2008) found attachment-related differences in RSA among 1-year-old infants in the strange situation (a fear-inducing situation). Regardless of attachment classification, infants tended to show expected vagal withdrawal (lowering of RSA) during separation, but infants with an avoidant attachment showed greater vagal withdrawal during separation in the strange situation than did securely attached infants. Also, unlike securely attached infants, avoidant infants did not appear to recover postseparation to baseline RSA levels. It is important to note that attachment-related differences in RSA do not always emerge (e.g., Gilissen, Bakermans-Kranenburg, van IJzendoorn, & van der Veer, 2008; Stevenson-Hinde & Marshall, 1999).

At times, apparently contradictory attachment-related differences in patterns of RSA have emerged. For example, Smith et al. (2016) found that secure preschool children had RSA that remained steady across the strange situation; avoidant children's RSA increased during the first separation, whereas ambivalent children's RSA decreased across the strange situation. Smith et al. (2016) suggested that these RSA patterns may reflect the emotional and behavioral regulation strategies associated with each of the attachment classifications. For example, the pattern of high RSA (vagal augmentation) found in the avoidant children may reflect use of PNS activation to cope with stressors, consistent with the deactivating strategies of insecure–avoidant children. In contrast, the pattern of low levels of RSA found in the ambivalent preschoolers might reflect the hyperactivation of negative emotion and the attachment figure as a source of challenge seen in ambivalent children. In contrast, Paret et al. (2015) used a paradigm involving exposure to a scary-but-interesting situation (interacting with a witch mask) and found that those with an ambivalent attachment lacked the vagal withdrawal (lowering of RSA) during the stressor that characterized the securely attached children. It is important to note, however, that these results held only among behaviorally inhibited preschoolers, with no such effect in children who were less inhibited. In sum, although links between specific attachment categories and RSA differ across samples that vary by age, by stress paradigm, and by child temperament, meaningful attachment-related differences in RSA have emerged and merit further study. Polyvagal theory provides a framework for understanding PNS activation and withdrawal across contexts in order to be able to relax when possible, yet engage with environmental challenges as needed.

To date, no study has examined whether increased attachment security has a *causal* influence on children's response to threat. Experimental research has been limited to links between attachment and negative emotions in response to threat in studies with nonhuman primates and mammals in which maternal availability or caregiving quality was manipulated (for reviews, see Polan & Hofer, 2016; Suomi, 2016).

Adult attachment researchers have used priming techniques to investigate whether temporary activation of mental representations of security improves behavioral and emotional threat responses. According to attachment theory, and consistent with social-cognitive theory (Schneider, 1991), attachment-related information filters through attachment mental representations, which, in turn, guide thoughts, feelings, and behaviors (Bowlby, 1969/1982, 1973). Mental representations of attachment develop based on past experiences in attachment-relevant situations. Thus, experiences with the availability and responsiveness of attachment figures are at the core of the mental representations of attachment that are subsequently brought to bear in novel attachment-relevant situations (Bowlby, 1973). Mental representations of security develop from experiences of one's attachment figures as sensitive and appropriately responsive. Mental representations of insecurity develop from experiences of attachment figures as rejecting, unavailable, ineffective, or frightening (Bowlby, 1969/1982, 1973; Main, Kaplan, & Cassidy, 1985).

It is well established that exposure to schema-relevant stimuli activates mental representation of interest (see Bargh, 2014). Thus, it follows that exposure to attachment security-relevant stimuli activate mental representations of security. Priming methodology extended to attachment research offers the possibility of exploring how mental representations of attachment drive affect, cognitions, and behavior in social and attachment-relevant situations using experimental methods (Mikulincer & Shaver, 2007). Adult attachment researchers have extended the use of priming techniques to investigate whether increased security leads to improved adult psychosocial outcomes—an idea central to attachment theory (Bowlby, 1973). Findings are consistent with attachment theory's predictions that secure mental representations cause: more adaptive responses to stress-inducing information; enhanced views of self and others; improved mood; increased concern, compassion, and empathy for others; and less aggressive behavior toward out-group members (see Mikulincer & Shaver, 2007). Furthermore, repeated security priming over the course of 2 weeks leads to decreased self-reported attachment-related anxiety, which suggests that security priming is, indeed, increasing accessibility to mental representations of attachment security (Carnelley & Rowe, 2007).

Considerable developmental research has demonstrated the utility of priming as a method for investigating how children's mental representations are causally related to brain activity, cognitive responses to events, and reactions to the social environment. In addition, *subliminal* priming techniques, which present priming stimuli below the threshold of conscious awareness (usually less than a 10th of a second), have been used with children as young as 6 years of age (see Stupica & Cassidy, 2014 for a review). Subliminal priming techniques are particularly useful for experimental research as they provide the opportunity to conduct double-blind experiments, thus reducing possible demand characteristics and experimenter bias. Given these previous studies that used priming methods, it seems reasonable to expect that subliminal attachment priming will prove to be useful in work with young children.

It is important to note that the effects of security priming may depend on past experiences of attachment security. For instance, it is possible that security priming is more effective for children who have had more experiences of available and sensitively responsive caregiving because there will be more attachment security experiences available to prime. Another possibility is that security priming may be relatively ineffective at enhancing positive psychosocial outcomes for children who are secure compared to those who are insecure because there is less room for improvement for secure individuals. Yet another possibility is that security priming is ineffective for those who have few experiences of others as sensitively responsive because there is no secure base script to activate.

On the other hand, it may be the case that the effects of security priming do not depend on past experiences and hence also do not depend on dispositional attachment. Specifically, Main (1990) argued that seeking proximity to an attachment figure under threatening situations is a primary biologically based behavioral strategy with which infants are born. If this is the case, it could be that infants are born with a rudimentary secure base script. Thus, security priming may tap into this basic secure base script and may not depend on dispositional security. Moreover, in order to have survived, all infants must have experienced at least some minimal experiences of having their distress responded to and alleviated (e.g., their hunger-related distress); even such minimal experiences may provide a sufficient experiential basis (if one is needed) for a priming effect. Similarly, Mikulincer and Shaver (2001) argued that because all humans have an attachment behavioral system, all humans, regardless of their dispositional attachment style, are potentially responsive to temporarily activated feelings of security. This position is generally supported by empirical adult research in which preexisting levels of security moderating the effects of security priming are the exception rather than the rule (see Mikulincer & Shaver, 2007).

Nonetheless, this lack of dispositional security as a moderator in the adult research may not extend to childhood. For example, it is possible that, compared to children, adults have had more experiences of their needs for comfort being met by a sensitively responsive person because they have more opportunities for intimacy outside of their relationships with their parents. As such, it may be rather uncommon to reach adulthood without having experienced one's needs for comfort and security being met, and it may be relatively more common for children to have few experiences of their needs for comfort and security being met.

Thus, dispositional security may moderate the effect of security priming in childhood.

The Present Study

In the present study, we examine whether subliminal attachment security primes decrease children's fear reactions, reduce SNS activation (relative to control primes), and increase PNS activation (relative to control primes). Our inclusion of a dispositional attachment measure allows us to examine whether dispositional attachment security is linked to lower fear reactions, lower SNS activation, and higher PNS activation relative to attachment insecurity, as well as to examine the moderating effects of dispositional attachment on responses to threatening stimuli following priming. We chose 6- and 7-year-old children as our participants because 6 years of age is the youngest age at which children have been successfully subliminally primed (see Stupica & Cassidy, 2014). Following most previous priming studies with adults (see Mikulincer & Shaver, 2007), we included a happy control condition, in addition to security priming and neutral control conditions, to rule out the alternative explanation that attachment security priming simply increases happiness. If the happiness prime control condition does not alter responses to threat and is no different from the neutral prime control condition, then it is reasonable to conclude that the effects of the attachment security prime condition are not due simply to increased feelings of happiness.

Based on attachment theory and prior research, we expected that, compared to children in both the happy and neutral control priming conditions, children in the security priming condition would have reduced EDA reactivity (assessed as change from baseline), increased RSA reactivity (assessed as change from baseline), fewer fearful facial expressions, and lower levels of self-reported fear in response to the threatening pictures. Similarly, based on theory and research, we expected dispositional attachment security to be associated with lower EDA reactivity, increased RSA reactivity, fewer fearful facial expressions, and lower levels of self-reported fear (as compared to dispositional attachment insecurity). It is important to clarify that our hypotheses regarding between-group differences in PNS activation focused on relative activation among the three groups. There is no previous research that would allow us to predict whether those receiving the attachment security primes or who were securely attached would demonstrate vagal augmentation in response to fear-inducing stimulus (i.e., increases in RSA above baseline level), or would instead simply demonstrate lower levels of vagal withdrawal (i.e., decreases in RSA from baseline, but to a lesser a degree than those in the two control groups) in response to fear-inducing pictures than would those who received control primes. Vagal augmentation would suggest an active regulatory response to the fear stressor, whereas lower levels of vagal withdrawal in the securely primed group than the control groups would indicate that the securely primed group was lowering PNS activation in order to attend to a stressor, but to a lesser degree than the control groups. Because the lack of previous research precluded selection between these two possibilities, we simply expected there to be significantly greater PNS activation in the secure prime group (relative to the control groups) and in the securely attached group (as compared to the insecurely attached). Finally, based on previous attachment priming studies with adults (see Mikulincer & Shaver, 2007), we did not expect dispositional attachment to moderate the effects of priming.

It was important to differentiate between children's physiological arousal in general and their responses to threat specifically. To do so, we presented children with two sets of stimuli: (a) pictures that were highly arousing and with a threatening valence and (b) pictures that were highly arousing and pleasant in valence. By comparing the effects of priming on children when viewing the arousing threatening pictures versus when viewing the arousing pleasant pictures, we were able to examine the effects of attachment security priming on physiological responses to threat specifically, rather than to arousal in general. We expected that priming would not produce the same pattern of effects when children viewed pleasantly arousing stimuli that was evident when children viewed threatening stimuli.

Method

Participants

Ninety 6- and 7-year-old (M = 6.95, SD = 0.61) children (42 girls) participated in a study about social and emotional events. Data collection occurred from June of 2011 to February of 2012. Recruitment was via flyers and newsletters distributed by schools in the greater Washington, DC area. As reported by mothers, children were racially and ethnically diverse: 50% Black/African

American, 49.3% White, 17.1% Hispanic or Latino, 3.9% Native American, 2.6% Asian, 1.3% Native Hawaiian or other Pacific Islander, and 1.1% Middle Eastern. Mother's mean age was 38.39 years (*SD* = 5.46, range = 25–47). Children's mean age was 6.95 years (*SD* = 0.61, range = 6.00–7.93). Most mothers were married (65.8%). The median household income was between $79,000 and $99,000 per year. Most mothers were native English speakers (89.5%), as were most children (98.7%). The only inclusionary criterion was that dyads were sufficiently fluent in English to complete the protocol in English.

Procedure

The present study is a 3 (prime: secure vs. happy control vs. neutral control) × 2 (order: threatening pictures first vs. pleasantly arousing pictures first) experimental design. Thirty children were randomly assigned to each priming condition. Early in the laboratory session, the physiological sensors (EDA, electrocardiogram, and respiratory effort) were placed on the child in the presence of the mother; the mothers then went to an adjacent room. The tasks related to the present study were then completed as follows: (a) a modified attachment story completion task (Bretherton, Ridgeway, & Cassidy, 1990; Cassidy, 1988), (b) training (and assessment) of emotion-labeling skills for a self-report measure, (c) a 60-s neutral valance picture presentation used for capturing a physiological baseline, and (d) the priming and arousing picture presentations, administered in an intertwined fashion as described next.

Priming and Arousing Picture Presentations

The procedures for the administration of the subliminal priming stimuli (one of three randomly assigned conditions: secure, happy, neutral) and the assessment of children's responses to the arousing picture presentations (all children saw both threatening sets and pleasantly arousing sets) were intertwined. These procedures occurred in two counterbalanced blocks. One block presented children with threatening arousing pictures and the other block presented children with pleasantly arousing pictures. The order of the blocks was counterbalanced through random assignment without replacement prior to the start of the laboratory session such that half the children saw the threatening pictures first and the other half of the children saw the pleasantly arousing pictures first. Each block comprised three sets of (a) a computerized subliminal priming task, (b) a computer-presented set of either threatening or pleasantly arousing pictures (depending on their randomly assigned order condition), and (c) children's self-reported emotional reactions recorded via paper and pencil. Between blocks, to reduce the possibility of carryover effects, children viewed a set of neutral pictures (a set that was different from the baseline set of neutral pictures) and reported their emotional reactions. Before beginning, children were trained on how to complete the tasks. The procedures for these tasks, which were completed on a computer programmed to run the protocol with MediaLab (Jarvis, 2010a) and DirectRT (Jarvis, 2010b), are described next.

Priming procedure. Priming occurred during a computer game in which children determined whether each picture in a series of 20 randomly presented pictures was an animal (e.g., cow, deer) or a plant (e.g., dandelion, ivy). Prior to viewing each cover picture (i.e., plant or animal), children were subliminally exposed to a picture prime. The computer game was completed a total of six times throughout the session: prior to viewing each of the three threatening picture sets (presented as a block) and each of the three pleasant arousal picture sets (presented as a block).

The picture prime was presented for 24 ms and was forward and backward masked by an image of multicolored television static presented for 500 ms immediately prior to and after the picture prime. Cover pictures were then presented until children told the experimenter whether the picture was an animal or a plant. Children were told that the image of multicolored television static that served as the forward and backward mask was the computer "thinking" about what picture to show the child next.

The three priming conditions and the attachment priming stimuli were chosen to parallel attachment security priming research with adults (see specifically, Mikulincer, Hirschberger, Nachmias, & Gillath, 2001, who used a black and white Picasso sketch of a mother and her infant to prime attachment security). Picture primes for children randomly assigned to the attachment security priming condition were of a mother having a caring interaction in close contact with her content child. Pictures of this nature were selected because they depicted a secure connection with an available and responsive mother that lacked avoidant and ambivalent/resistant behavior on the part of the child. Security priming pictures were selected by compiling a set of pictures freely available on the Internet that matched the above criteria. In order to create a final set of attachment security priming pictures that represented infants and children, boys and girls, and race/ethnicity equally, the pictures were categorized accordingly. Then, to choose which pictures would serve as security priming stimuli, five attachment researchers were asked to rank the pictures within each category from most representing attachment security to least representing attachment security. For the set of pictures depicting infants, the two pictures with the highest average ranks were selected from each race/ethnicity category, resulting in eight pictures with infants. For pictures depicting children, the picture with the highest average rank was selected from each race/ethnicity by child sex category, resulting in eight pictures with children.

Priming pictures for children randomly assigned to the happy control condition were of adult humans with Duchenne smiles from the University of Bolton Affect Recognition Tri-Stimulus Approach (BARTA; Lawrence, Abdel-Nabi, & Charlton, 2011). Happy priming pictures were selected so that sex (man or woman), age, (young or old), and race/ethnicity (White, Black, Asian, Hispanic/Latino) were equally represented. Within each of these categories, pictures with the highest "happy" rating according to the developers of the BARTA were selected resulting in 16 happy priming pictures. Given that our participants were children in an age range that is frequently in the care of nonattachment figures (e.g., teachers, babysitters, coaches), we chose to use pictures of adults as opposed to children to rule out the possibility that the secure priming condition simply reflects an effect of the presence of a friendly adult.

To match both (a) previous neutral priming conditions in the adult attachment priming literature (e.g., Mikulincer & Shaver, 2001) and (b) the complexity of the security and happy priming stimuli, priming pictures for children randomly assigned to the neutral control condition were multicolored polygons. These priming stimuli were created by making pictures that had one shape (i.e., square, triangle, pentagon, octagon) duplicated 16 times within each picture. The shapes overlapped each other. Then, the pictures were rotated 90° right, 180° right, and 90° left, resulting in four pictures of each shape. Each of the pictures was then filled in with 40 colors (i.e., five shades each of eight colors) resulting in 16 unique, multicolored, and complex geometric control priming pictures.

Presentations of neutral, threatening, and pleasantly arousing stimuli. As noted earlier, children's responses to the threatening stimuli as a function of priming group were the principal study foci; responses to pleasantly arousing stimuli were examined to test whether physiological responses were specific to threat rather than to arousal in general. The threatening and pleasantly arousing pictures were shown within the two experimental blocks described earlier; the neutral pictures were shown when assessing a physiological baseline and between the two blocks to reduce carryover effects. All pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). Selection from within the IAPS set was based on ratings by children and/or adults in studies that the IAPS developers conducted (Lang et al., 2008). *Neutral pictures* were selected from the common objects category from the IAPS because these pictures had been rated as having neither unpleasant nor pleasant valence and low arousal. *Threatening pictures* were taken from the animal attack category of the IAPS because these pictures had been rated as fear inducing, unpleasant, and highly arousing. *Pleasantly arousing pictures* were selected from the adventure, sports, and food categories because they had been rated as pleasantly arousing. Each picture presentation consisted of a set of 20 pictures, each picture presented for 3 s.

Measures

Attachment

Children completed a modified attachment story completion task designed following the procedure described in Bretherton et al. (1990) and Cassidy (1988). Dolls and other props were arranged to tell the beginning of a story. Girls were given girl dolls to use as the protagonist, and boys were given boy dolls to use as the protagonist. After the experimenter presented the child with the story stem, the child was asked to tell the rest of the story. Following a warm-up/practice story (School Day: "This is Janie and she's waiting for the bus to take her to school. The school bus is here! What happens next?"), each of the four story stems presented the child with a different attachment-relevant scenario (i.e., a distressing event happens to the child in the presence of the parents: the child hurts his or her knee [*hurt knee*: "Bobby's mom is watering the flowers and his dad is raking leaves. Bobby tripped on a rock and hurt his knee while he was running to the swing set! Ouch! It's bleeding! What happens next?"], hears a scary noise at night [*scary noise*: "It's night time and Janie is asleep until she hears a scary noise and she can't go back to sleep! What happens next?"], ruins a favorite painting [*wet painting*: "Bobby's mom and dad are washing the dishes while Bobby finishes his painting at the table. He is really proud of his picture. Oh no! As Bobby got up from the table, the glass of water spilled all over his painting! Oh no! What happens next?"], and gets lost [*getting lost*: "Janie is at the store with her mom. Janie is walking behind her mom and looking at all of the different things on the shelves. 'Oh no!' says Janie. 'I'm lost!' What happens next?"]). This method of assessing attachment security in early childhood has desirable psychometric properties including good concordance with attachment classifications obtained from separation and reunion procedures and good predictive validity (for a review, see Solomon & George, 2016).

Children's responses to the story completions were transcribed verbatim to include the children's actions with the dolls and props. Transcripts were coded using a 5-point scale for secure base script content by two coders trained by Harriet Waters. The coding scheme was developed using the key elements of a secure base script that Waters and Waters (2006) outlined (i.e., a child and attachment figure(s) are constructively occupied; the child becomes distressed and asks for help; an attachment figure responds appropriately, sensitively, and effectively; the child and attachment figure(s) return to constructive activities). Possible scores ranged from 5 (*high secure base content*) to 1 (*no secure base content present*).

Disagreements were conferenced. Reliability for the hurt knee, scary noise, and lost stories was high (intraclass correlation coefficients [ICC] were .92, .96, and .97, respectively). Because of substantially lower agreement (ICC = .72) on the wet painting story, this story was not included. Scores ranged from 1 to 5 (M = 2.88, SD = 0.97). Intercoder agreement was high (ICC = .99) for the composite score. For analytic simplicity, children's scores were split at the median coding score (i.e., 3). There were 40 children whose composite score was 3 or greater (secure) and 50 children whose composite score was below 3 (insecure). Results remained unchanged when analyses were conducted with continuous attachment scores but interpretation is facilitated by this categorical distinction.

Children's EDA

An experimenter applied an odor-free, hypoallergenic silver chloride gel to the silver chloride EDA electrodes. Then, an experimenter attached these two electrodes to the palmar surfaces of the index and middle finger on the second phalanges of children's nondominant hand using double-sided adhesive disks, elasticized Velcro bands, and paper tape.

EDA was assessed continuously using a Biopac MP 150 system (BIOPAC Systems, Goleta, CA, USA) and AcqKnowledge v4.1. The system was calibrated to zero before the start of each session. EDA was sampled at a rate of 1,000 samples per second at a gain of 5 $\mu\Omega$/V and 10 Hz. The average EDA during each block of picture presentations was extracted from the graphs.

Children's EDA scores during the threatening pictures were averaged to create a mean EDA score. Following convention and to control for children's baseline levels of EDA and to save degrees of freedom in our analyses, children's mean EDA during the first block of neutral pictures presented was subtracted from their mean EDA during the threatening pictures and from their mean EDA during the pleasantly arousing pictures. These difference scores were used as the dependent variables in our two principal analyses and served as our marker for children's level of SNS arousal.

Children's RSA

RSA is a noninvasive measure of heart rate variability linked to breathing that is a marker of PNS activation (Oveis et al., 2009; Porges, 1995; Sloan & Epstein, 2005). In the present study, RSA was derived from continuous assessments of electrocardiography (ECG) and respiratory activity. ECG was assessed continuously using a Biopac MP 150 system and AcqKnowledge v4.1 software at 1,000 samples per second in millivolts using a bipolar configuration with a sensor placed in the depression beneath each clavicle. This placement decreases movement artifacts. To assess respiratory activity, a respiration belt was secured around children's ribcage under children's arms to reduce movement artifacts. Respiration was recorded continuously using a Biopac MP 150 system and AcqKnowledge v4.1 at 1,000 samples per second in volts.

RSA was calculated using the fully automated RSA algorithm in AcqKnowledge v4.2. The program locates and marks each inspiration and expiration cycle, creates a tachogram of the R-R interval, and measures the minimum and maximum R-R intervals during each respiration cycle. For each breath cycle, breath-to-breath values, duration of the cycle, minimum R-R interval, maximum R-R interval, and the RSA value are calculated and exported to an Excel file. Each RSA score represents the difference between the minimum and maximum R-R intervals for each breath cycle, resulting in an RSA score expressed in milliseconds for each cycle (ms/cycle). The average RSA during the threatening and pleasantly arousing pictures were averaged separately. RSA during the set of neutral pictures was subtracted from each of these scores to create a difference score and thus control for individual difference in RSA. Higher levels of RSA indicate greater PNS activation.

Children's Facial Expressions

Three coders certified reliable on Ekman's Facial Action Coding System (FACS; Ekman & Friesen, 1978; Paul Ekman Group, n.d.) and blind to the study's hypotheses and information about the participants coded children's facial expressions using frame-by-frame "scrubbing" from high-definition video recordings. Two independent research assistants coded each video. Each frame was examined for evidence of the following facial expressions: fear, anger, sadness, disgust, contempt, happiness, and surprise. Only facial expressions of fear were of interest in the present study. Coders' tallies were averaged. The number of frames that fearful facial expressions observed was tallied for each threatening and pleasantly arousing picture presentation. These tallies were averaged, separately for the threatening and pleasantly arousing picture valences resulting in a score that reflected the average number of frames that fearful facial expressions were observed during each picture presentation valence. Reliability was excellent (ICC = .96, $p < .001$).

Children's Self-Reported Emotions

To circumvent problems that may be present due to the verbal abilities of young children, Durbin's (2010) protocol was used. This protocol allowed children to indicate their emotional state using a visual analog scale and a set of five pictures of children displaying facial expressions of discrete emotions. The photographs displaying the five emotions were judged to represent prototypical expressions of happiness, sadness, anger, fear, and surprise using Ekman and Friesen's (1978) FACS. The experimenter showed children each picture and asked them to label the expression. Forty-one children (45.6%) were able to identify all five discrete emotions on the first attempt.

Children rated their emotions by circling one of five thermometers: 5% full (*almost none or very little*), 25% full (*a little bit*), half full (*medium*), 75% full (*a lot*), and 100% full (*very much or a whole lot*) under each picture on a worksheet following the baseline neutral picture presentation and following each set of threatening and pleasantly arousing picture presentations. Children's fear scores were averaged separately across the three threatening picture sets and across the three pleasantly arousing picture sets.

Missing Data

Data were missing for four children who were unable to complete the attachment or picture presentation parts of the study. Data were missing completely at random as indicated by a Little's MCAR test, $\chi^2(7) = 8.77$, $p = .270$. To improve generalizability and reduce the possibility of Type I error, we used maximum likelihood estimation and all available data to impute missing outcome values. This approach allowed us to test our hypotheses with improved power and less biased parameter estimates than other techniques (Graham, 2009).

Results

Preliminary Analyses

To determine whether random assignment to condition and order resulted in groups that were equivalent in terms of demographic variables and attachment security, analyses of variance (ANOVAs) were conducted to assess possible associations between condition and order for child age (respectively: $F[2, 87] = 1.04$, $p = .357$, $d = 0.215$; $F[2, 88] = 0.09$, $p = .760$, $d = 0.063$) and child attachment (respectively: $F[2, 87] = 0.46$, $p = .632$, $d = 0.143$; $F[2, 88] = 2.61$, $p = .110$, $d = 0.341$); chi-square analyses were conducted to assess possible associations between condition and order for child race/ethnicity (whether or not the child was a racial or ethnic minority; respectively: $\chi^2[2] = 3.71$, $p = .157$, $d = 0.302$; $\chi^2[1] = 2.74$, $p = .098$, $d = .354$) and child sex (respectively: $\chi^2[2] = 3.31$, $p = .191$, $d = 0.278$; $\chi^2[1] = .43$, $p = .512$, $d = 0.139$). These analyses indicate that random assignment created groups that were roughly equivalent in terms of child age, attachment, race/ethnicity, and sex.

Manipulation Check

We conducted a manipulation check with the 30 children exposed to the neutral prime to establish that the stimuli in the threatening condition did in fact evoke more facial expressions of fear and greater self-reported fear than the neutral pictures which were presented to establish a baseline and the pleasantly arousing pictures. As expected, children had more frequent fearful facial expressions when viewing the threatening pictures (M = 596.22, SE = 13.34) compared to the neutral baseline (M = 59.77, SE = 1.25; $M_{\text{difference}}$ = 536.46, SE = 12.56, p < .001, d = 4.639) and the pleasantly arousing pictures (M = 323.88, SE = 16.13; $M_{\text{difference}}$ = 272.34, SE = 4.92, p < .001, d = 2.786). Similarly, children's self-reported fear was higher when viewing the threatening pictures (M = 1.23, SE = 0.25) compared to the neutral baseline (M = 0.68, SE = 0.29; $M_{\text{difference}}$ = 0.58, SE = 0.33, p = .084, d = 0.382) and the pleasantly arousing pictures (M = 0.72, SE = 0.15; $M_{\text{difference}}$ = 0.51, SE = 0.22, p = .020, d = 0.409).

Raw Score Differences in Responses to Stimuli Within Priming Groups

Across all priming conditions, repeated measures ANOVAs indicated the fear-inducing pictures were associated with significant changes in participants' EDA and RSA raw scores (see Table 1). Consistent with expectation, however, only the secure prime condition showed a significant *reduction* in EDA (i.e., decreased SNS activation) compared to baseline (t[29] = 2.36, p = .025); the neutral prime group (t[29] = −6.74, p < .001) and the happy prime group (t[29] = −6.05, p < .001) both exhibited a significant *increase* in EDA compared to baseline. Contrary to expectation, all of the priming groups showed a significant increase in RSA (increased PNS activation, i.e., vagal augmentation), in response to the fear-inducing pictures (secure prime: t[29] = 3.09, p = .003; happy prime: t[29] = 5.14, p < .001; neutral prime: t[29] = 4.36, p < .001).

The pleasant exciting pictures were associated with a significant *decrease* in EDA (SNS activation) for all of the priming groups (secure prime: t[29] = 13.00, p < .001; happy prime: t[29] = −5.66, p < .001; neutral prime: t[29] = −6.74, p < .001) and a significant increase in RSA for all the priming groups (secure prime: t[29] = 5.61, p < .001; happy prime: t[29] = 12.73, p < .001; neutral prime: t[29] = 17.26, p < .001).

Table 1
Means and Standard Deviations for EDA and RSA Raw Scores for Each Priming Condition (Neutral Control, Happy Control, Security) Across Each Picture Valence (Neutral Baseline, Fear, Pleasant Excitement)

Picture valence	Neutral control M (SD)	Happy control M (SD)	Security M (SD)
EDA raw scores			
Neutral baseline	9.27 (5.53)$_a$	9.53 (6.34)$_a$	8.26 (5.31)$_a$
Fear	12.79 (5.08)$_b$	11.60 (2.63)$_b$	3.33 (1.82)$_b$
Pleasant excitement	5.05 (1.74)$_c$	10.23 (1.60)$_c$	16.60 (2.56)$_c$
RSA raw scores			
Neutral baseline	62.42 (7.43)$_a$	64.66 (7.62)$_a$	63.32 (6.85)$_a$
Fear inducing	65.62 (16.03)$_b$	66.96 (19.06)$_b$	75.58 (26.71)$_b$
Pleasant excitement	94.09 (11.94)$_c$	95.02 (10.99)$_c$	95.20 (11.43)$_c$

Note. n = 30 per cell. For each dependent variable, within each priming condition, cells with different subscripts are significantly different from each other at p < .05 (one-tailed). EDA = electrodermal activity; RSA = respiratory sinus arrhythmia.

Principal Analyses

To determine the effects of priming condition and children's attachment on children's reactions to threatening pictures, we conducted four generalized estimating equations analyses with order (threatening first vs. pleasantly arousing pictures first), condition (security prime vs. happy prime vs. neutral prime), child attachment (secure vs. insecure), and valence (threatening vs. pleasantly arousing) entered as factors. A full factorial model was specified using an unstructured correlation matrix and the Type III sums of squares approach. Rather than examining the threatening pictures and pleasantly arousing pictures in separate analyses and eliminate the factor of valence, we chose to run a model that included reactions to both valence conditions because the standard errors would be more accurate and our results more valid. Moreover, this analytic approach allowed us to accomplish both (a) the study's principal goal of examining the effects of priming condition and children's attachment on children's reactions to threatening pictures, and (b) the goal of testing for the specificity of priming effects. The findings for children's reactions to threatening stimuli are reported in this Principal Analyses section. The findings for children's reactions to pleasantly arousing pictures are then reported in the subsequent section.

The effects of interest in these models are (a) the interaction between priming condition and valence, (b) the interaction between child attachment and valence, and (c) the three-way interaction among priming condition, child attachment, and valence. As is convention, only the highest order significant interaction is probed, which in this case means that if the three-way interaction is significant, the lower order two-way interactions are not probed. If statistically significant, these effects of interest were probed using two-tailed significance tests with the estimated marginal means obtained from the omnibus analyses. For the sake of parsimony, the effects of order, which were experimentally and statistically controlled and were not of interest, are presented only in Table 2 and are not probed.

EDA

The priming condition and valence interaction was statistically significant (see Figure 1 and Table 2). As such, we probed the priming effects within the threatening pictures condition. As expected, change in EDA from baseline was lowest for children in the secure priming condition compared to the happy priming ($M_{\text{difference}} = 6.59$, $SE = 0.95$, $p < .001$, $d = 1.791$) and neutral priming conditions ($M_{\text{difference}} = 8.11$, $SE = 1.14$, $p < .001$, $d = 1.837$). The happy and neutral priming conditions did not differ from each other ($M_{\text{difference}} = 1.52$, $SE = 1.27$, $p = .231$, $d = 0.309$). Also as expected, securely attached children ($M = -0.37$, $SE = 0.81$) had lower levels of EDA in response to threatening stimuli compared to insecurely attached children ($M = 4.99$, $SE = 0.44$; $M_{\text{difference}} = 5.36$, $SE = 0.92$, $p < .001$, $d = 1.236$). The three-way interaction among priming condition, child attachment, and valence was not statistically significant (see Table 2), which indicates that priming effects on threatening stimuli are not moderated by child attachment.

Table 2
Effects of Priming (P), Order (O), Attachment (A), and Valence (V) on Children's Reactions

Variable	EDA Wald χ^2	RSA Wald χ^2	Fearful expressions Wald χ^2	Reported fear Wald χ^2
P	6.52*	50.96*	10,978.95*	3.94
O	0.31	0.50	6.37*	0.39
A	125.32*	846.96*	9,936.35*	0.09
V	27.69	579.32	22,302.85*	19.91*
P × O	2.99	0.72	6.73*	0.00
P × A	0.72	6.32*	8.44*	0.08
P × V	1,121.05*	77.84*	0.22	2.06
O × A	0.68	0.53	5.48*	0.46
O × V	0.73	0.05	6.06*	11.20*
A × V	103.42*	65.97*	4.95*	1.89
P × O × A	0.72	0.29	3.98	3.27
P × O × V	0.30	0.55	3.48	4.68
P × A × V	1.05	14.18*	86.60*	3.16
O × A × V	0.65	3.37	0.44	4.98*
P × O × A × V	0.64	4.20	4.90	2.86

Note. EDA = electrodermal activity; RSA = respiratory sinus arrhythmia.
*$p < .05$.

RSA

The three-way interaction among priming condition, child attachment, and valence was significant (see Figure 2). As such, we probed the interaction between priming condition and valence when children were viewing the threatening pictures separately for secure children and insecure children. For secure children, the secure priming condition had the highest levels of RSA augmentation (from baseline) to threatening pictures compared to the happy priming ($M_{\text{difference}} = 20.58$, $SE = 3.99$, $p < .001$, $d = 1.95$) and the neutral priming conditions ($M_{\text{difference}} = 18.85$, $SE = 2.18$, $p < .001$, $d = 3.402$). The happy and neutral priming conditions did not differ from each other ($M_{\text{difference}} = 1.73$, $SE = 3.89$, $p = .657$, $d = 0.175$). For insecure children, the same pattern emerged such that the secure priming condition had the highest levels of RSA augmentation (from baseline) compared to the happy priming ($M_{\text{difference}} = 11.65$, $SE = 3.74$, $p = .002$, $d = 1.101$) and the neutral priming conditions ($M_{\text{difference}} = 8.17$, $SE = 2.15$, $p < .001$, $d = 1.306$). The happy and neutral priming conditions did not differ from each other ($M_{\text{difference}} = 3.48$, $SE = 3.82$, $p = .362$, $d = 0.313$). Given that the pattern of effects for priming condition within the threatening pictures was the same for secure and insecure children, we probed secure versus insecure differences within each priming condition for the threatening pictures to determine how a three-way interaction emerged. Comparisons of secure versus insecure children indicated that secure children had higher RSA augmentation (from baseline) within each priming condition for the threatening pictures (secure priming: $M_{\text{difference}} = 31.72$, $SE = 2.19$, $p < .001$, $d = 5.301$; happy priming: $M_{\text{difference}} = 22.79$, $SE = 5.01$, $p < .001$, $d = 1.665$; neutral priming: $M_{\text{difference}} = 21.04$, $SE = 2.15$, $p < .001$, $d = 3.647$). These analyses indicate that, although a statistical interaction for child attachment emerged, the effects of priming were not moderated by child attachment security.

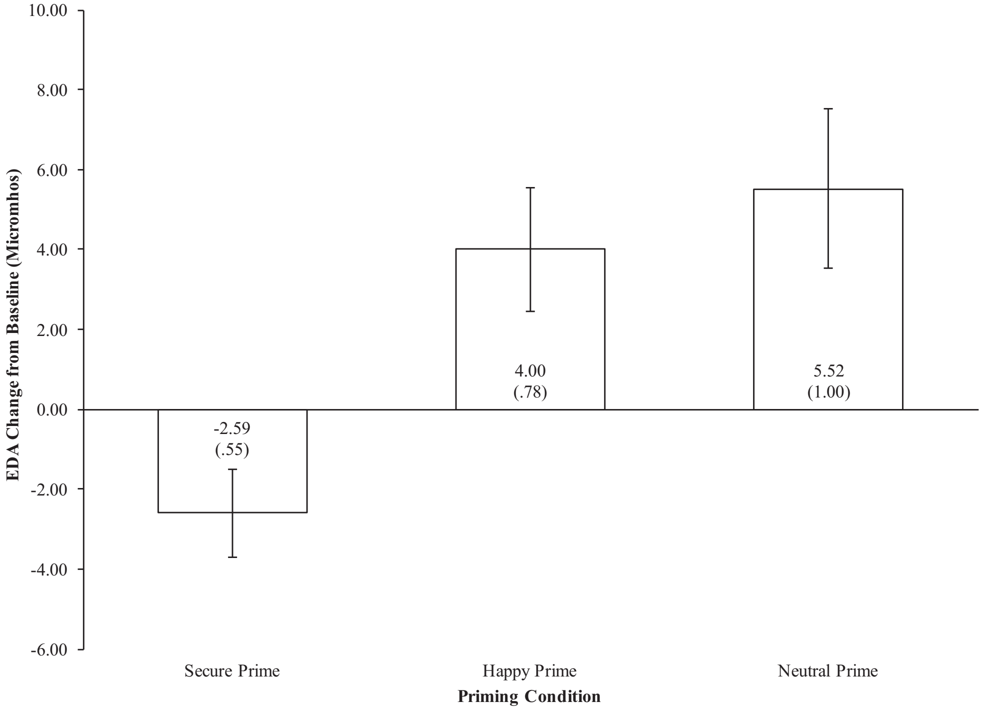

Figure 1. Children's electrodermal activity (EDA) change from baseline scores (in micromhos) in response to threatening pictures as a function of priming condition. Error bars represent 95% confidence intervals such that overlapping error bars indicate nonsignificant differences.

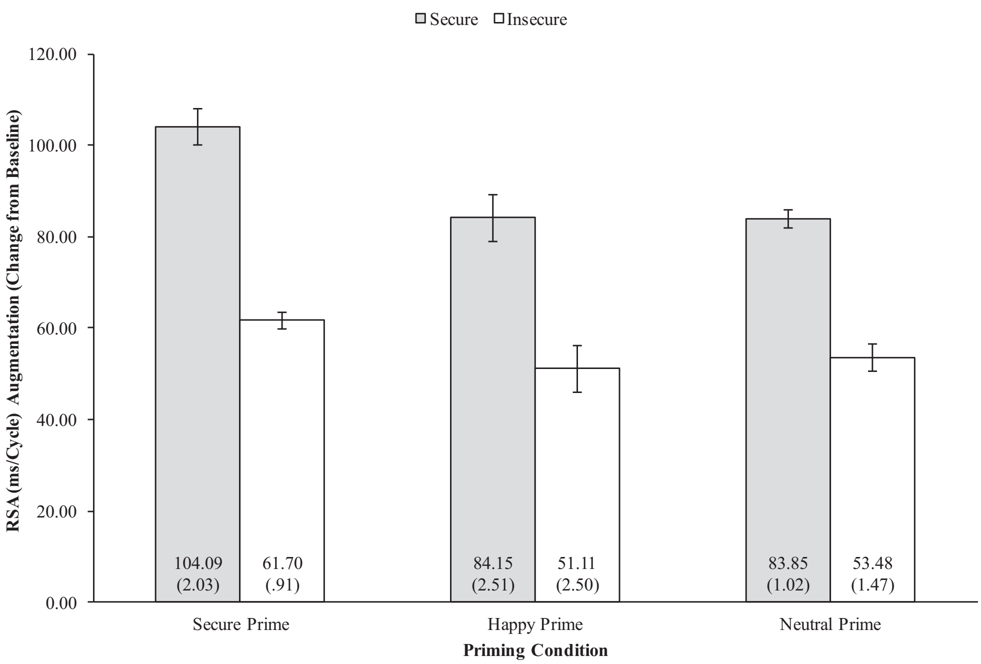

Figure 2. Children's respiratory sinus arrhythmia (RSA; in milliseconds per respiration cycle) augmentation (change from baseline) responses to threatening pictures as a function of priming condition and child attachment. Error bars represent 95% confidence intervals such that overlapping error bars indicate nonsignificant differences.

Fearful Facial Expressions

The three-way interaction of priming condition, child attachment, and valence was significant (see Figure 3). As such, we probed the interaction between priming condition and valence when children were viewing the threatening pictures separately for secure children and insecure children. For secure children, the secure priming condition had the fewest fearful facial expressions compared to the happy priming ($M_{\text{difference}} = 168.64$, $SE = 4.25$, $p < .001$, $d = 14.998$) and neutral priming conditions ($M_{\text{difference}} = 171.63$, $SE = 4.24$, $p < .001$, $d = 15.924$). The happy and neutral priming conditions did not differ from each other ($M_{\text{difference}} = 2.99$, $SE = 4.53$, $p = .509$, $d = 0.260$). Similarly, for insecure children, the secure priming condition had the fewest fearful facial expressions compared to the happy priming ($M_{\text{difference}} = 149.74$, $SE = 4.96$, $p < .001$, $d = 10.674$) and neutral priming conditions ($M_{\text{difference}} = 142.38$, $SE = 5.11$, $p < .001$, $d = 9.574$). Again, given that the pattern of effects for priming condition within the threatening pictures was the same for secure and insecure children, we probed secure versus insecure differences within each priming condition for the threatening pictures to determine how a three-way interaction emerged. Comparisons of secure versus insecure children indicated that secure children had fewer fearful facial expressions within each priming condition for the threatening pictures (secure priming: $M_{\text{difference}} = 171.68$, $SE = 3.64$, $p < .001$, $d = 17.261$; happy priming: $M_{\text{difference}} = 291.11$, $SE = 3.90$, $p < .001$, $d = 27.317$; neutral priming: $M_{\text{difference}} = 143.43$, $SE = 5.56$, $p < .001$, $d = 9.614$). These analyses indicate that, although a statistical interaction for child attachment emerged, the effects of priming are not moderated by child attachment security.

Self-Reported Fear

Contrary to our expectations, neither the interaction between priming condition and valence nor the interaction between child attachment and valence was significant. The same is true for the interaction among priming condition, child attachment, and valence (see Table 2).

Specificity of Priming Effects

Here we report analyses designed to examine whether priming effects on physiological responses (i.e., EDA and RSA) were specific to threatening stimuli specifically or physiological arousing pictures more broadly. By definition, a significant interaction between priming condition and valence indicates that priming effects differ as a function of whether pictures were threatening or pleasantly arousing. As can be seen in Table 2, a significant interaction between priming condition and valence (threatening vs. pleasantly arousing) emerged for both EDA and RSA, which provides evidence that different priming effects emerged for threatening and pleasantly arousing pictures. Probing of these interactions in the principal analyses (presented earlier) revealed that the effects of priming on EDA and RSA were in the expected direction with secure priming producing the lowest EDA and highest RSA compared to the happy and neutral control conditions. Next, the effects of priming condition are probed within the pleasantly arousing pictures and compared to those obtained for the threatening pictures. Again, as is convention, we probed the three-way interaction among priming condition, child attachment, and valence when it is statistically significant.

EDA

As reported in Table 2, the interaction between priming condition and valence was statistically significant, which indicates that the priming effects that held for the threatening pictures were not evident for the pleasantly arousing pictures. For the pleasantly arousing pictures, scores were highest for children in the secure priming condition ($M = 11.15$, $SE = 0.63$) compared to children in the happy ($M = 2.71$, $SE = 0.75$; $M_{\text{difference}} = 8.45$, $SE = 0.98$, $p < .001$, $d = 2.226$) and neutral priming conditions ($M = -1.63$, $SE = 0.64$; $M_{\text{difference}} = 12.78$, $SE = 0.90$, $p < .001$, $d = 3.666$). Also for the pleasantly arousing pictures, children in the happy priming condition had higher EDA than children in the neutral priming condition ($M_{\text{difference}} = 4.33$, $SE = 0.98$, $p < .001$, $d = 1.14$). This pattern of findings is nearly opposite from that found for threatening stimuli.

RSA

As expected, priming effects were different for threatening versus pleasantly arousing pictures. The three-way interaction among priming condition, child attachment, and valence was significant. For secure children, RSA did not differ as a function of priming condition. Specifically, secure children's RSA reactivity to pleasantly arousing pictures in the secure priming condition ($M = 103.90$,

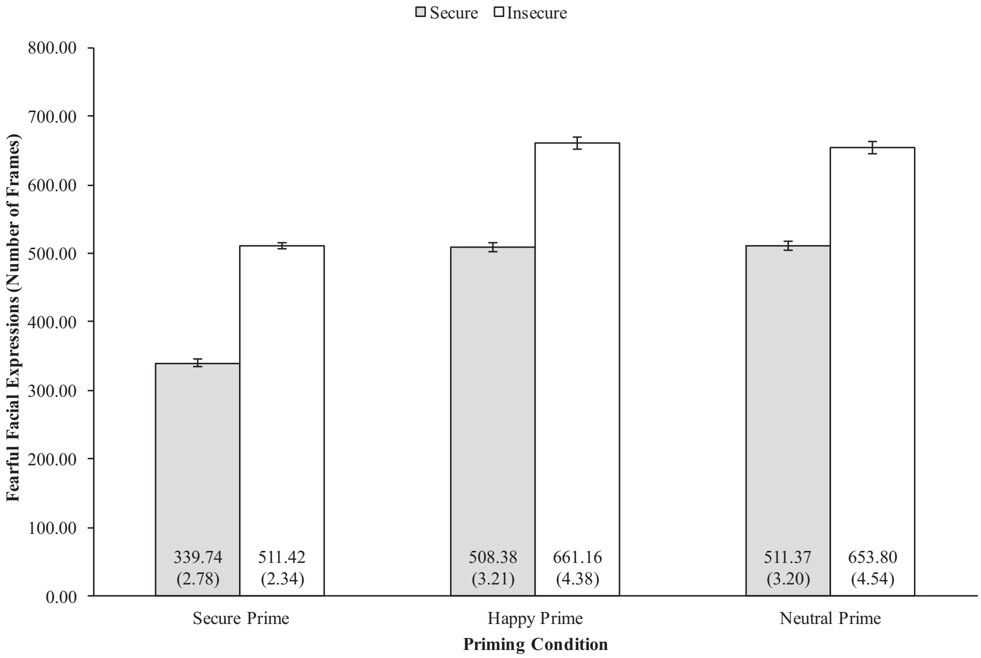

Figure 3. Children's fearful facial expressions (in number of frames fear was observed) in response to threatening pictures as a function of priming condition and child attachment. Error bars represent 95% confidence intervals such that overlapping error bars indicate non-significant differences.

$SE = 1.25$) was statistically the same as secure children's RSA reactivity to pleasantly arousing pictures in the happy ($M = 105.60$, $SE = 1.40$; $M_{\text{difference}} = 1.70$, $SE = 1.88$, $p = .365$, $d = 0.342$) and neutral priming conditions ($M = 107.03$, $SE = 1.61$; $M_{\text{difference}} = 3.14$, $SE = 2.03$, $p = .123$, $d = 0.609$). The same pattern emerged for insecure children such that insecure children's RSA reactivity to pleasantly arousing pictures in the secure priming condition ($M = 84.84$, $SE = 1.34$) was statistically the same as insecure children's RSA reactivity to pleasantly arousing pictures in the happy ($M = 85.82$, $SE = 1.27$; $M_{\text{difference}} = 0.97$, $SE = 1.84$, $p = .597$, $d = 0.186$) and neutral priming conditions ($M = 85.34$, $SE = 1.28$; $M_{\text{difference}} = 0.47$, $SE = 1.80$, $p = .792$, $d = 0.090$). In sum, priming had no effect on children's RSA reactivity to pleasantly arousing pictures, which was not the case for children's RSA reactivity to threatening pictures (wherein an expected priming effect emerged).

Discussion

Understanding children's responses to threat is fundamental to understanding nearly all aspects of children's well-being, including social, emotional, cognitive, and physiological functioning, as well as the development of psychopathology and physical disease (Shonkoff & Phillips, 2000). Correlational evidence and clinical observations have led many researchers and clinicians to assume that attachment quality plays a substantial causal role as a regulator of children's responses to threat. This study provides preliminary evidence that exposure to images designed to evoke mental representations of attachment security reduces fear responses in children. This study also found corroborating correlational evidence that children's dispositional attachment security is linked to decreased fear.

After having been exposed to subliminally presented attachment security picture primes, 6- and 7-year-old children had greater reductions in EDA, greater increases in RSA, and fewer fearful facial expressions during observations of threatening pictures than children subliminally exposed to happy or neutral picture primes. Due to the inclusion of a happy priming condition in which children were subliminally exposed to pictures of adults with Duchenne smiles, the possibility that attachment security primes simply primed positive affect can be ruled out. Moreover, the fact that the present study used pictures of smiling adults for the happy control condition rules out the possibility that the attachment priming pictures reduced fear simply because of the presence of an adult.

Our use of the language "exposure to images designed to evoke mental representations of attachment security" stems from our acknowledgment that we cannot be certain that our intention to temporarily increase children's representations of attachment security was successful. There is no way of knowing with certainty the nature of children's internal representations or security following experimental manipulation. Yet an assumption that the experimental security manipulation temporarily increases attachment security follows the long-standing assumptions, contained within over 50 years of experimental priming research, that exposure to targeted stimuli influences people's thoughts, moods, behaviors, and physiology, presumably partly through changing their internal world (see Bargh, 2014 for a history and review of priming research). What is clear from the results of our study is that children's subliminal exposure to attachment-related photographs influenced their physiology and facial expressions in theoretically predicted ways that exposure to other photographs (of happy and neutral valence) did not.

Until the present study, the large body of attachment security priming studies has been limited to research with adults and older teenagers. The present study demonstrates that attachment security priming can, indeed, be a useful method for determining whether increased access to mental representations of attachment security is causally linked to child development outcomes; this study provides experimental evidence that exposure to images designed to evoke mental representations of attachment security through priming decreases the physiological "fight or flight" response assessed via EDA, increases the physiological relaxation response assessed via RSA, and decreases fearful facial expressions during exposure to fear eliciting stimuli.

Our selection of the stimuli used in the happy prime condition allowed an important extension of adult attachment priming research. Specifically, Mikulincer et al. (2001) used a treasure chest full of jewels and coins as their happy prime; because children's understanding of wealth differs from that of adults, we felt unsure that this stimulus would induce happiness in children. Moreover, our selection of the happy control stimulus was driven by a desire to portray happiness in relation to a social stimulus. As such, we chose to use adults showing a Duchenne smile (a universal signal of positive affect; Murphy & Zajonc, 1993) as our happy prime stimuli, which allowed the opportunity to extend the attachment priming literature by comparing established security primes to a *social* happy control prime condition. Mikulincer et al. stated that they did not use happy faces because of concerns that happy faces may activate positive memories of the faces of attachment figures. Our findings do not support this concern because happy face primes were, in fact, distinct from attachment security primes with the latter but not the former predicting decreased fear reactions, decreased EDA relative to baseline, and increased RSA augmentation in response to threat. Thus, a reasonable assertion is that being primed with images that evoke mental representations of attachment security (a mother having a caring interaction in close contact with her content child) decreases fear reactions and increases physiological regulation in response to threat and that these effects are distinct from effects resultant from being primed with social stimuli that are universal signals of positive affect. It seems then, that there is something special about being primed with mother and child cuddled together in warm interaction that is not present with happy social stimuli. Future work will strengthen the claim that it is very specifically attachment as opposed to other forms of social interaction (e.g., activation of the affiliative/peer system) by presenting additional sorts of control conditions.

In research examining physiological markers of emotional reactions, it is necessary to rule out the possibility that effects result simply from changes in arousal in general. In this study, in order to isolate physiological markers of fear reactivity, we included a block of pleasantly arousing stimuli to compare to our arousing and unpleasant threatening stimuli. The finding that the hypothesized priming effects that emerged for threatening stimuli did not replicate for the pleasantly arousing stimuli strengthens our conclusions that experimentally induced security attenuates the physiological "fight or flight" mechanism, and increases PNS activation in the context of threat. One compelling possibility that may help to explain the present data is that priming attachment security results in changes in social cognition, such that potentially threatening pictures were perceived to be nonthreatening, allowing for decreases in EDA and increases in PNS in the context of threat. Future research may be able to examine potential mechanisms for the links between security priming and physiology.

In the present study, it is *attenuation* of fear that is associated with both dispositional and primed attachment security. Indeed, this finding supports the core of Bowlby's (1973) thinking—that confidence in the attachment figure's availability is central in reducing fear. Yet there is some indication that when emotion reactivity is considered more broadly, predictions (and related findings) are nuanced and complex. Although security decreases fear, it would not be expected (nor has it been the case) that security decreases all negative emotions. In fact, in some cases it is *greater* emotionality, even negative emotionality, that is associated with security. For instance, 3-year-olds who had been secure as infants showed a *greater* tendency, compared to those who had been insecure, to share their sadness when losing a competitive game with an experimenter (Lütkenhaus, Grossmann, & Grossmann, 1985). The thinking is that security is associated with experiences wherein a wide range of emotions, including negative emotions, have been accepted and sensitively responded to; thus, in negatively arousing contexts, secure children are more likely to engage in open, direct, and active expression because of confidence that such expression allows for help in dealing with the distress (Cassidy, 1994). Even in adolescence, when asked to play a frustrating computer game with their mothers, individuals who had been secure as infants were found to express and report more anger (Spangler & Zimmermann, 2014). Yet to our knowledge, no evidence exists of secure children expressing greater fear than insecure children. Examination of the ways in which security is linked to greater versus lower emotion reactivity as a function of type of emotion, context, presence/absence of others—particularly an attachment figure, cause of the emotion, nature of assessment (observations, self-report, parent report), and developmental period are all important avenues for future research.

Study findings revealed intriguing (and unexpected) effects of attachment security priming on pleasantly arousing stimuli. Specifically, secure priming led to the greatest EDA reactivity to pleasantly arousing stimuli, in contrast to the lowest EDA reactivity in response to the threatening pictures. It is possible that future research will find that attachment security supports greater physiological flexibility in responding to the environment. Findings that security (Hazen & Durrett, 1982) and maternal availability (Sorce & Emde, 1981) enhance children's exploration of novel environments are convergent with the possibility that heightened EDA in the secure prime condition may reflect a physiological readiness to interact with positively arousing stimuli. Because this study was not designed to address the issue of how security influences children's reactions to positive stimuli, these findings must be taken only as a starting point for future research that tackles this issue intentionally.

In contrast to children's physiological and expressive fear responses, children's self-reported fear reactions did not vary as a function of priming group. It is interesting to note that our self-report findings converge with those of a longitudinal study examining 12-year-olds who participated in a "talk show" task designed to elicit fearfulness (Spangler & Zimmermann, 2014); even though infant insecurity predicted greater fearfulness in the task at 12 years as reported by mothers, no attachment group differences emerged for *self-reported* fearfulness. Despite this convergence, additional factors may have played a role in the present study with younger children. It may be that children's poor emotion-labeling skills played a role. Notably, only 46% of children initially correctly labeled all the expressions. Most importantly, the most frequent emotion mislabeled was fear—a particular problem given that children's fear reactions were the cornerstone of this study. An additional consideration was the time delay (typically several minutes) that occurred between priming and the assessments of children's self-reported fear, a delay that may have allowed children's fear to dissipate.

The present study also found that, similar to the adult attachment priming literature, the effects of priming were not moderated by child attachment security. We did, however, find a statistical interaction that reflected different baseline levels of fear for secure and insecure children such that secure children were less fearful than insecure children with security priming effects building from these different initial levels. Notably, results showed there was no "ceiling effect" for secure children, who experienced the same changes in fear reactions induced by secure priming that were evidenced in insecure children. We also saw that, despite having insecure mental representations of attachment, secure priming reduced the expected effects of fear reactions. The present findings can be viewed as converging with the notion that because all humans are born with an attachment behavior system (Bowlby, 1969/1982, 1973; Main, 1990), sufficient secure base knowledge appears to be present and can be activated to allow security priming to be effective even in insecure individuals (see Mikulincer & Shaver, 2007). Whether this knowledge involves an innate schema or one built from experience is beyond the scope of this article and is a compelling direction for future research.

In sum, this study provides initial evidence that exposure to images designed to evoke mental representations of attachment security decreases children's fear reactivity. These findings mesh with the extensive correlational evidence that attachment security is associated with reduced fear in children. This study also extends the well-established body of literature in adults that has employed brief manipulations of mental representations of attachment security to change attachment-related outcomes (e.g., empathy, altruism, views of the self and others, exploration, concern for self and others, and mood and mental health; for reviews, see Mikulincer & Shaver, 2007). In addition to extending security priming research to include children, the present study is the first to indicate that exposure to images designed to evoke mental representations of attachment security relate to physiological outcomes. It is important to underscore that priming does nothing to change children's core attachment security, which reflects a variety of factors and is relatively stable (Bowlby, 1969/1982, 1973; Vaughn, Egeland, Sroufe, & Waters, 1979; Waters, 1978). Nonetheless, our temporary manipulation of children's accessibility to feelings of security is an important step in increasing our understanding of how children's mental representations of a sensitively available and responsive caregiver drive their reactions to their environment.

References

Bargh, J. A. (2014). The historical origins of priming as the preparation of behavioral responses: Unconscious carryover and contextual influences of real-world importance. *Social Cognition*, *32*, 209–224. https://doi.org/10.1521/soco.2014.32.supp.209

Borelli, J. L., Crowley, M. J., David, D. H., Sbarra, D. A., Anderson, G. M., & Mayes, L. C. (2010). Attachment and emotion in school-aged children. *Emotion*, *10*, 475–485. https://doi.org/10.1037/a0018490

Bowlby, J. (1973). *Attachment and loss* (Vol. II: Separation). New York, NY: Basic Books.

Bowlby, J. (1982). *Attachment and loss* (Vol. I: Attachment). New York, NY: Basic Books. (Original work published 1969)

Bretherton, I., Ridgeway, D., & Cassidy, J. (1990). Assessing internal working models of the attachment relationship: An attachment story completion task for 3-year-olds. In M. Greenberg, D. Cicchetti, & E. M. Cummings (Eds.), *Attachment in the preschool years: Theory, research, and intervention* (pp. 273–308). Chicago, IL: University of Chicago Press.

Carnelley, K. B., & Rowe, A. C. (2007). Repeated priming of attachment security influences later views of self and relationships. *Personal Relationships*, *14*, 307–320. https://doi.org/10.1111/j.1475-6811.2007.00156.x

Cassidy, J. (1988). Child-mother attachment and the self in six-year-olds. *Child Development*, *59*, 121–134. https://doi.org/10.2307/1130394

Cassidy, J. (1994). Emotion regulation: Influences of attachment relationships. In N. Fox (Ed.), The development of emotion regulation, *Monographs of the Society for Research in Child Development*, *59*, (2-3, Serial No. 240), 228–249.

Duchesne, S., Ratelle, C. F., Poitras, S., & Drouin, E. (2009). Early adolescent attachment to parents, emotional problems, and teacher-academic worries about the middle school transition. *The Journal of Early Adolescence*, *29*, 743–766. https://doi.org/10.1177/0272431608325502

Durbin, C. (2010). Validity of young children's self-reports of their emotion in response to structured laboratory tasks. *Emotion*, *10*, 519–535. https://doi.org/10.1037/a0019008

Ekman, P., & Friesen, W. V. (1978). *Facial action coding system*. Palo Alto, CA: Consulting Psychologist Press.

Gilissen, R., Bakermans-Kranenburg, M. J., van IJzendoorn, M., & Linting, M. (2008). Electrodermal reactivity during the Trier social stress test for children: Interaction between the serotonin transporter polymorphism and children's attachment representation. *Developmental Psychobiology*, *50*, 615–625. https://doi.org/10.1002/dev.20314

Gilissen, R., Bakermans-Kranenburg, M. J., van IJzendoorn, M. H., & van der Veer, R. (2008). Parent–child relationship, temperament, and physiological reactions to fear-inducing film clips: Further evidence for differential susceptibility. *Journal of Experimental Child Psychology*, *99*, 182–195. https://doi.org/10.1016/j.jecp.2007.06.004

Graham, J. W. (2009). Missing data analysis: Making it work in the real world. *Annual Review of Psychology*, *60*, 549–576. https://doi.org/10.1146/annurev.psych.58.110405.085530

Granot, D., & Mayseless, O. (2001). Attachment security and adjustment to school in middle childhood. *International Journal of Behavioral Development*, *25*, 530–541. https://doi.org/10.1080/01650250042000366

Graziano, P., & Derefinko, K. (2013). Cardiac vagal control and children's adaptive functioning: A meta-analysis. *Biological Psychology*, *94*, 22–37. https://doi.org/10.1016/j.biopsycho.2013.04.011

Hazen, N. L., & Durrett, M. E. (1982). Relationship of security of attachment to exploration and cognitive mapping abilities in 2-year-olds. *Developmental Psychology*, *18*, 751–759. https://doi.org/doi: 10.1037/0012-1649.18.5.751

Hill-Soderlund, A. L., Mills-Koonce, W. R., Propper, C., Calkins, S. D., Granger, D. A., Moore, G. A., & Cox, M. J. (2008). Parasympathetic and sympathetic responses to the Strange Situation in infants and mothers from avoidant and securely attached dyads. *Developmental Psychobiology*, *50*, 361–376. https://doi.org/10.1002/(ISSN)1098-2302

Jarvis, B. G. (2010a). *MediaLab (v2010.8.0)* [computer software]. New York, NY: Empirisoft.
Jarvis, B. G. (2010b). *DirectRT (v2010.8.0)* [computer software]. New York, NY: Empirisoft.
Kochanska, G. (2001). Emotional development in children with different attachment histories: The first three years. *Child Development*, *72*, 474–490. https://doi.org/10.1111/1467-8624.00291
Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual*. Technical Report A-8. University of Florida, Gainesville, FL.
Lawrence, L., Abdel-Nabi, D., & Charlton, J. (2011, May). *The BARTA (University of Bolton Affect Recognition Tri-Stimulus Approach): "A systematic journey from emoticons to humans via toontown."* Paper presented at the BPS Annual Conference, Glasgow, UK.
Lütkenhaus, P., Grossmann, K. E., & Grossmann, K. (1985). Transactional influences of infants' orienting ability and maternal cooperation on competition in three-year-old children. *International Journal of Behavioral Development*, *8*, 257–272. https://doi.org/10.1177/016502548500800302
Main, M. (1990). Cross-cultural studies of attachment organization: Recent studies, changing methodologies, and the concept of conditional strategies. *Human Development*, *33*, 48–61. https://doi.org/10.1159/000276502
Main, M., Kaplan, N., & Cassidy, J. (1985). Security in infancy, childhood, and adulthood: A move to the level of representation. In I. Bretherton & E. Waters (Eds.), *Growing points in attachment theory and research, Monographs of the Society for Research in Child Development*, *50*, (1-2, Serial No. 209), 66–104. https://doi.org/10.2307/3333827
Mikulincer, M., Hirschberger, G., Nachmias, O., & Gillath, O. (2001). The affective component of the secure base schema: Affective priming with representations of attachment security. *Journal of Personality and Social Psychology*, *81*, 305–321. https://doi.org/10.1037/0022-3514.81.2.305
Mikulincer, M., & Shaver, P. R. (2001). Attachment theory and intergroup bias: Evidence that priming the secure base schema attenuates negative reactions to out-groups. *Journal of Personality and Social Psychology*, *81*, 97–115. https://doi.org/10.1037/0022-3514.81.1.97
Mikulincer, M., & Shaver, P. R. (2007). Boosting attachment security to promote mental health, prosocial values, and inter-group tolerance. *Psychological Inquiry*, *18*, 139–156. https://doi.org/10.1080/10478400701512646
Murphy, S. T., & Zajonc, R. B. (1993). Affect, cognition, and awareness: Affective priming with optimal and suboptimal stimulus exposures. *Journal of Personality and Social Psychology*, *64*, 723. https://doi.org/10.1037/0022-3514.64.5.723
Oveis, C., Cohen, A. B., Gruber, J., Shiota, M. N., Haidt, J., & Keltner, D. (2009). Resting respiratory sinus arrhythmia is associated with tonic positive emotionality. *Emotion*, *9*, 265–270. https://doi.org/10.1037/a0015383
Paul Ekman Group (n.d.). *Facial action coding system*. Retrieved from https://www.paulekman.com/product-category/facs/
Paret, L., Bailey, H. N., Roche, J., Bureau, J., & Moran, G. (2015). Preschool ambivalent attachment associated with a lack of vagal withdrawal in response to stress. *Attachment & Human Development*, *17*, 65–82. https://doi.org/10.1080/14616734.2014.967786
Polan, H., & Hofer, M. A. (2016). Psychobiological origins of infant attachment and its role in development. In J. Cassidy & P. R. Shaver (Eds.), *Handbook of attachment: Theory, research, and clinical applications* (3rd ed., pp. 117–132). New York, NY: Guilford.
Porges, S. W. (1995). Orienting in a defensive world: Mammalian modifications of our evolutionary heritage: A polyvagal theory. *Psychophysiology*, *32*, 301–318. https://doi.org/10.1111/j.1469-8986.1995.tb01213.x
Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology*, *74*, 116–143. https://doi.org/10.1016/j.biopsycho.2006.06.009
Schneider, D. (1991). Social cognition. *Annual Review of Psychology*, *42*, 527–561. https://doi.org/10.1146/annurev.ps.42.020191.002523
Shonkoff, J. P., & Phillips, D. A. (Eds.). (2000). *From neurons to neighborhoods: The science of early childhood development*. Washington, DC: National Academy Press.
Sloan, D. M., & Epstein, E. M. (2005). Respiratory sinus arrhythmia predicts written disclosure outcome. *Psychophysiology*, *42*, 611–615. https://doi.org/10.1111/j.1469-8986.2005.347.x
Smith, J. D., Woodhouse, S. S., Clark, C. A., & Skowron, E. A. (2016). Attachment status and mother-preschooler parasympathetic response to the strange situation procedure. *Biological Psychology*, *114*, 39–48. https://doi.org/10.1016/j.biopsycho.2015.12.008
Solomon, J., & George, C. (2016). The measurement of attachment security and related constructs in infancy and early childhood. In J. Cassidy & P. R. Shaver (Eds.), *Handbook of attachment: Theory, research, and clinical applications* (3rd ed., pp. 366–398). New York, NY: Guilford.
Sorce, J. F., & Emde, R. N. (1981). Mother's presence is not enough: Effect of emotional availability on infant exploration. *Developmental Psychology*, *17*, 737–745. https://doi.org/10.1037/0012-1649.17.6.737
Spangler, G., & Zimmermann, P. (2014). Emotional and adrenocortical regulation in early adolescence: Prediction by attachment security and disorganization in infancy. *International Journal of Behavioral Development*, *38*, 142–154. https://doi.org/10.1177/0165025414520808
Stevenson-Hinde, J., & Marshall, P. (1999). Behavioral inhibition, heart period, and respiratory sinus arrhythmia: An attachment perspective. *Child Development*, *70*, 805–816. https://doi.org/10.1111/1467-8624.00058
Stevenson-Hinde, J., & Shouldice, A. (1990). Fear and attachment in 2.5-year-olds. *British Journal of*

Developmental Psychology, *8*, 319–333. https://doi.org/10.1111/j.2044-835X.1990.tb00848.x

Stupica, B., & Cassidy, J. (2014). Priming as a way of understanding children's mental representations of the social world. *Developmental Review*, *34*, 77–91. https://doi.org/10.1016/j.dr.2013.12.003

Suomi, S. J. (2016). Attachment in rhesus monkeys. In J. Cassidy & P. R. Shaver (Eds.), *Handbook of attachment: Theory, research, and clinical applications* (3rd ed., pp. 133–134). New York, NY: Guilford.

Vaughn, B., Egeland, B., Sroufe, L. A., & Waters, E. (1979). Individual differences in infant-mother attachment at twelve and eighteen months: Stability and change in families under stress. *Child Development*, *50*, 971–975. https://doi.org/10.2307/1129321

Waters, E. (1978). The reliability and stability of individual differences in infant-mother attachment. *Child Development*, *49*, 483–494. https://doi.org/10.2307/1128714

Waters, H. S., & Waters, E. (2006). The attachment working models concept: Among other things, we build script-like representations of secure base experiences. *Attachment & Human Development*, *8*, 185–197. https://doi.org/10.1080/14616730600856016