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THE DEVELOPMENT OF INFANT EMOTION REGULATION

Time Is of the Essence

Naomi V. Ekas, Julie M. Braungart-Rieker, and Daniel S. Messinger

The ability to effectively regulate emotions is considered a hallmark of early social and emotional development and is associated with a variety of developmental outcomes. Emotion regulation is a dynamic process that involves the temporal sequencing of emotion and behavioral strategies. Despite an increased interest in and investigation of emotion regulation, however, there is little attention given to these temporal dynamics. Infancy is an especially important period during which to examine these dynamics as early development is associated with the greatest changes in emotion regulation, and emotion regulation skills, and these skills are reliably linked to later developmental outcomes (Feldman, 2009). This chapter aims to present research that focuses on the temporal dynamics of emotion regulation during infancy by presenting: (1) an overview of the development of emotion regulation during infancy; (2) traditional, global approaches to the measurement of emotion regulation during infancy; and (3) temporal, moment-to-moment sequencing of emotion and regulatory strategies with an emphasis on the methodological and statistical approaches to studying temporal associations. Finally, we highlight new statistical techniques that would allow researchers to further unravel the complexities of emotion regulation during this time period.

Emotion Regulation: Definition and Developmental Sequelae

Emotion regulation is the process of monitoring, evaluating, and modifying emotional reactions to accomplish one's goals (Thompson, 1994). Notably, emotion regulation may affect the intensive and temporal features of the emotion such as the intensity, speed of onset or recovery, persistence over time, and the lability of the emotion (Thompson, 1994). During the emotion regulation process, individuals generally deploy strategies aimed at modifying several aspects of the emotion, including the intensity and duration of the emotion. There are developmental processes that influence the ability to regulate emotional arousal. These include, but are not limited to, fine and gross motor skills, neurophysiological systems, and attention mechanisms (Feldman, 2009; Fox, Kirwan, & Reeb-Sutherland, 2012; Thompson, 1994). As a result of these maturational changes, an individual's repertoire of emotion regulation strategies differs as a function of age, beginning with reflexive, motor-based strategies in the first months of life to sophisticated reappraisal strategies that emerge later in the life span. Kopp (1989) suggests that newborn behaviors typically consist of initially reflexive actions such as rooting and sucking, which may assist in regulating emotions. Until about two months of age, infant looking behavior is relatively constrained, a phenomenon referred to as *obligatory attention* (e.g., Hunnius & Geuze, 2004; Reynolds & Romano, 2016). For example, during face-to-face interactions, infants will look almost continuously at their parent's face (Kaye & Fogel, 1980). By 3 months of age, however, infants gain increasing control over their motor actions. They may be able to volitionally control their attention via head movements or voluntarily move their hands to their mouth to engage in self-soothing behaviors. Between 3 months and 7–9 months, infants begin to develop cognitive skills necessary for more complex regulatory strategies (Kopp, 1989). Infants' memory improves during this period and they are better able to anticipate events. Infants gradually gain increasing awareness of their arousal states and are able to modify these states by engaging in a variety of behaviors. For example, by 6 months of age, infants are able to flexibly shift their attention (Calkins & Hill, 2007), which can enable them to shift attention away from a distressing situation. Finally, by the end of the first year, infants gain the ability to communicate with gestures and develop early language skills. Increased fine motor skills allow infants to reach for and grasp objects. Improved gross motor skills also allow infants the ability to physically control the environment. Kopp (1989) suggests that the most important advance at this age concerns the social aspects of emotion regulation. Infants are able to manipulate their caregiver's behavior and they are also able to actively recruit others when they need help.

Emotion regulation is also interpersonal in nature such that an individual's emotions are regulated via interactions with another individual. One interactional partner's behavior and emotions influence the other partner's behavior and emotions (Cole, Martin, & Dennis, 2004; Ostlund, Measelle, Laurent, Conradt, & Ablow, 2017). During early infancy, infants traditionally rely on their caregiver to regulate their emotions (Kopp, 1989). For example, when an infant displays distress the caregiver may respond by modifying their own emotional expressions to match the infant's (e.g., showing a concerned expression; Tronick & Cohn, 1989), by engaging in soothing behaviors (e.g., rocking, caressing, etc.), or by assisting in distracting the infant (e.g., pointing to interesting objects in the room). Gradually, across the first year, as the infant develops more sophisticated regulatory strategies, they rely less on their caregiver to regulate their emotions and are able to deploy these strategies earlier in the emotion regulation process (Kopp, 1989).

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For example, in the first months of life an infant may display visible signs of distress (e.g., crying); the caregiver responds by redirecting the infant's attention to a toy, and the infant's negative emotions gradually dissipate. Several months later we observe a change in this process: the infant shows signs of escalating negative emotion (e.g., fussing and whining), and before the caregiver can respond the infant turns their head and shifts their attention away from the source of frustration. This marks an important shift in the development of emotion regulation skills that will continue throughout the toddler and preschool years.

Measurement of Emotion Regulation during Infancy: Global Measures of Emotion and Strategy Use

As discussed earlier, emotion regulation is dynamic process that, during infancy, is influenced by maturational processes and interpersonal interactions. However, historically, such dynamic processes have typically been inferred from research using global measures. Indices of emotion regulation during infancy often consist of assessing levels of negative emotion, typically anger or fear, and the use of putative regulatory strategies (e.g., Buss & Goldsmith, 1998; Ekas, Braungart-Rieker, Lickenbrock, Zentall, & Maxwell, 2011; Frankel, Umemura, Jacobvitz, & Hazen, 2015). To assess emotion regulation, infants are often placed in situations designed to elicit distress (e.g., the Still Face Paradigm, arm restraint, toy removal, introduction of novel object) and their facial expressions and behavior are observed. In these situations, longer durations of facial expressions and greater intensities of negative emotion are generally thought to reflect poor emotion regulation (e.g., Bridges, Connell, & Grolnick, 1997). With respect to purported regulatory strategies, greater use of strategies such as self-soothing (e.g., thumb sucking), and visual disengagement from the distressing stimuli are thought to reflect better emotion regulation skills (Gianino & Tronick, 1988; Mangelsdorf, Shapiro, & Marzolf, 1995; Parritz, 1996; Rothbart, Ziaie, & O'Boyle, 1992). Unfortunately, global measures of emotion and behavioral strategy use fail to capture the dynamics of emotion regulation. That is, higher levels of negative emotion only indicate that the emotion was activated and cannot provide information about whether the emotion is being regulated. For example, an infant with high negative emotion may be regulating from even higher levels. Similarly, the use of visual disengagement or self-soothing does not allow one to discern whether the behavioral strategy serves a regulatory function. An infant putting their hand in their mouth may have no effect on negative emotion.

In their now seminal work, Cole and colleagues (2004) suggested several methodological directions for the study of emotion regulation that aim to capture the dynamics of emotion regulation. First, independent measurement of the activated emotion and the putative regulatory strategy is necessary. Cole et al. (2004) argue that using the level of negative emotion to indicate whether an individual is effectively regulating their emotions is a potential confound as it does not allow one to study the regulating and regulated aspects of emotion. In addition, it is important that researchers are able to make strong inferences that the emotion being studied was indeed present. For example, situations in which the infants' goals have been blocked (e.g., arm restraint) or expectations are violated (e.g., Still Face Paradigm) afford the opportunity for infants to experience and regulate anger or frustration; the exposure to novel stimuli (e.g., stranger approach) is likely to stimulate feelings of fear. However, in neither situation can one be confident that the emotional reaction occurred if that reaction is not measured. In such situations, researchers studying emotion regulation should separately measure both the activated emotion, often through facial expressions and vocalizations, and the putative behavioral strategies, such as direction of gaze and self-soothing (e.g., Braungart-Rieker et al., 1998; Buss & Goldsmith, 1998; Crockenberg & Leerkes, 2004; Ekas et al., 2011; Ekas, Lickenbrock, & Braungart-Rieker, 2013; Stifter & Braungart, 1995). Newer research has also begun to incorporate physiological indices of emotion, such as heart rate variability and skin conductance (Calkins & Johnson, 1998, Feldman, 2009; Morasch & Bell, 2011), providing a multimodal assay of the activated emotion.

Fortunately, a burgeoning body of research has included distinct measures of the activated emotion and behavioral strategies. Early on, this body of research attempted to capture the process of emotion regulation by examining correlational associations between emotional expressions and behavioral strategy use using scores that were aggregated across the task. This design offered a first step in identifying behavioral strategies that may be effective at regulating emotions. In one illustrative study, Braungart-Rieker et al. (1998) found that 4-month-old infants who exhibited greater negative emotion averaged over the entire Still Face Paradigm showed less overall self-soothing and objective orientation during the task. Likewise, Diener, Mangelsdorf, McHale, and Frosch (2002) found significant correlations between infants' emotional expressions and strategy use during a competing demands task. Specifically, higher levels of overall distress were associated with more self-soothing and less distraction across the task, whereas infants who exhibited more positive emotion showed more social referencing, distraction, and engaging the parent. The relative effectiveness of a given behavioral strategy is inferred via the strength and direction of the correlation, such that an inverse relationship suggests that the particular strategy is effective at regulating negative emotion. Although studies employing correlational techniques provide important information concerning the role of behavioral strategies in the regulatory process, they do not allow for the inference that the strategy led to an increase or decrease in the activated emotion.

Measurement of Emotion Regulation during Infancy: Temporal Associations between Emotions and Behavioral Strategies

The process of emotion regulation involves a *change* in the activated emotion (Cole et al., 2004; Thompson, 1994). Thus, for example, at any time the individual may deploy strategies aimed at changing the intensity of the emotion. If the strategy is effective, we would expect to witness a change in the activated

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Regulation during Infancy: ween Emotions and Behavioral

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emotion. For example, if an infant is experiencing distress and engages in self-soothing, a reduction in subsequent distress would suggest that self-soothing is effective at regulating negative emotion. In addition to ensuring the independent measurement of the activated emotion and the putative regulatory strategies, Cole et al. (2004) urged researchers to examine the temporal associations between these variables. By examining temporal associations, researchers can assess the extent to which the intensity of an infant's emotion changes *as a result of* performing a specific behavioral strategy. If a behavioral strategy serves a regulatory purpose, then we would expect a decrease or increase in the activated emotion following the use of that strategy. Thus, examining temporal associations can capture the moment-to-moment dynamics within the process of emotion regulation.

Examining the temporal associations between the activated emotion and behavioral strategies requires researchers to incorporate micro-level measures of emotion and strategies. Scores capturing the proportion of time spent displaying negative emotion or engaging in self-soothing are not sufficient. Multiple time-sequenced measures of the activated emotion and behavioral strategies are necessary. Early research assessing these temporal associations often measured emotion and strategy use in 5 s, 10 s, or 15 s epochs (Buss & Goldsmith, 1998; Stifter & Braungart, 1995; Diener & Mangelsdorf, 1999). Newer research has utilized 1 s intervals (Ekas et al., 2011; Ekas et al., 2013a; MacLean et al., 2014) or measured variables continuously (Crockenberg & Leerkes, 2004). In addition, researchers are also required to utilize statistical techniques that move beyond simple correlations. Studies examining temporal associations have employed change scores (Stifter & Braungart, 1995), and used contingency analyses (e.g., Buss & Goldsmith, 1998; Crockenberg & Leerkes, 2004; Diener & Mangelsdorf, 1999). Newer research has incorporated contingency and sequential analyses within multilevel models (Ekas et al., 2011; Ekas et al., 2013a; MacLean et al., 2014). Despite the differing time scales and statistical analyses, each of these studies shared a common goal of examining the *process* of emotion regulation. The following sections examine the use of change scores (including contingency analyses) and multilevel models in the study of infant emotion regulation. Details on model specifications and results from studies utilizing these methods are also presented below.

Examining Temporal Associations Using Change Scores

The first known study to examine the temporal associations between emotion and behavioral strategies utilized change scores (Stifter & Braungart, 1995). This study of 5- and 10-month-old infants used negative vocalizations as an indicator of emotion and coded the following regulatory strategies: avoidance (composite of escape behaviors and scanning without focusing on object), orientation (composite of eyes focused on mother or object), self-comforting behaviors, and communicative behaviors (composite of gestures and vocalizations). These were coded during an arm restraint task at 5 months of age and a toy removal task at 10 months of age, both designed to elicit anger. A single score representing the peak level of negative emotion was coded for each 10 s epoch. The presence of regulatory strategies was coded continuously and a score representing the mean number of seconds per 10 s epoch was calculated. To determine whether a given strategy was associated with a change in negative emotion, a change score from epoch to epoch was computed. For example, if negative emotion during a given 10 s epoch was 5 and then during the next 10 s epoch the negative emotion score was 3, then the change score would be −2, indicating that there was a decrease in the intensity of negative emotion.

Next, three groups of epochs were formed on the basis of the epoch-to-epoch change score: decreasers (negative emotion decreased from one epoch to the next), increasers (negative emotion increased from one epoch to the next), and no change. Thus, the *degree* of change was not used in analyses. Repeated measures analysis of variance with the change group as the independent variable and concurrent behavioral strategy use as the dependent variable was used to test the study hypotheses. At 5 months of age, orientation was more likely to occur during periods of decreases in negative emotion, suggesting that focusing attention on the mother or an object in the room were effective strategies for regulating negative emotion. At 10 months of age, orientation was not significantly associated with changes in negative emotion; however, self-comforting behaviors were more likely to occur when negative emotion was decreasing. Thus, the results suggest that orientation and self-comforting may be effective strategies for regulating negative emotions at different ages. This study represented an important first step in identifying strategies associated with concurrent *changes* in negative emotion; however, the calculation of change scores and the statistical techniques used did not allow for a more nuanced determination that the strategies *led* to decreases in negative emotion.

Two later studies utilized a similar approach to examine the effect of putative regulatory strategies on the regulation of fear and anger in 6- to 24-month-old infants (Buss & Goldsmith, 1998; Diener & Mangelsdorf, 1999). In both studies, researchers identified when a behavioral strategy occurred and then examined whether the intensity of the emotional expression (fear or anger) changed in the next epoch. The total number of "increases," "decreases," and "no changes" was calculated. Observed frequencies were computed from the epochs in which a putative regulatory strategy occurred. In addition, in order to conduct comparisons with the observed frequencies, the rate of increases, decreases, and no changes across epochs when a putative regulatory strategy did not occur was also calculated. Next, chi-square analyses were conducted to compare the observed frequency of increases, decreases, and no changes when the behavioral strategy did occur compared to the base rates when it did not occur. Thus, researchers were able to determine whether the observed values were different than what would have been expected by chance, given the base rates when the behavioral strategy did not occur. The two studies that utilized this analytic approach are described in detail below.

Buss and Goldsmith (1998) examined char
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Buss and Goldsmith (1998) examined changes in fear and anger at 6, 12, and 18 months of age. Fear and anger were examined during situations designed to elicit each respective emotion. For example, anger was assessed during an arm restraint task and when an attractive toy was placed behind a barrier. Fear was examined during presentation of a remote controlled spider and a mechanical dog. The peak intensity of fear and anger facial expressions and vocalizations were measured during 5 s or 10 s epochs (dependent on task). A variety of putative regulatory behaviors were coded as present or absent during each epoch including looking at mother/experimenter, visual distraction, reach for toy, withdrawal, and interacting with stimulus. The results of the chi-square analyses indicated that, in the fear-eliciting tasks, only withdrawal from the fearful stimulus (i.e., mechanical dog) was associated with a decrease in the expression of fear. This strategy may function in a similar manner to the orientation behaviors coded in Stifter and Braungart (1995), described earlier. Redirecting behavior away from the source of distress (e.g., fearful stimulus or unavailable toy) may be an effective way for infants to distract themselves. On the other hand, during the anger tasks, each of the putative regulatory strategies (looking at mother/experimenter, visual distraction, reach for toy, and interacting with stimulus) were associated with a reduction in anger in the following epoch. Although associated on an epoch-by-epoch level in the anger episodes, overall correlations between levels of anger and use of behavioral strategies were unrelated. Consistent with the call to action of Cole et al. (2004), temporal associations were key to uncovering the dynamics of emotion regulation.

In a cross-sectional study, Diener and Mangelsdorf (1999) examined the temporal associations between fear and anger and behavioral strategies in 18- and 24-month-olds. The study consisted of two anger-eliciting (toy removal and delay of gratification) and two fear-eliciting (mechanical octopus and monster puppet) episodes. Fear, anger, and behavioral strategies were coded in 15 s epoch from infants' emotional expressions and assigned an intensity score. The following behavioral strategies were coded as present or absent: fussing to mother, help seeking, social referencing, engaging the mother, distraction, leave-taking, avoidance, playing with the stimulus, problem solving with toy, tension release, and self-soothing. Across emotion-eliciting episodes, fussing to the mother was associated with decreases in negative emotion. In this study, fussing to the mother was defined as negative vocalizations directed to the mother and excluded generalized distress; thus, it was considered to be separate from negative emotion. However, other strategies varied as a function of the emotional context. Similar to Buss and Goldsmith's (1998) results, avoidance was associated with declines in fear, but not anger. One strategy commonly assumed to regulate negative emotion, distraction, was associated with the maintenance of anger and not with changes in fear. This was surprising because averting gaze is generally thought to be a strategy that infants use to reduce distress. Similarly, self-soothing was also associated with the maintenance of anger and not associated with changes in fear. It is possible that the effectiveness of strategies changes as a function of age, such that strategies that were effective during the first year of life were no longer effective among the 2-year-olds seen in Diener and Mangelsdorf (1999). In addition, the time scale used in the current study, 15 s epochs, may have been too long to capture the moment-to-moment changes in negative emotion that may be taking place. Overall, the results of this study suggest that strategies commonly thought to regulate negative emotion (e.g., distraction, self-soothing) based on correlational evidence were not significantly associated with *changes* in negative emotion.

The studies described above coded behaviors using epochs of varying lengths (5 s to 15 s); however, advances in computing, particularly statistical software programs, have allowed emotion regulation researchers to measure infant emotion and behavior at a micro, moment-to-moment level. For example, instead of measuring target behaviors in 5 s or 15 s epochs, which may only capture the peak or average level of emotion, researchers can easily and at relatively low cost measure behavior in 1 s intervals or conduct continuous ratings of behavior (Chow, Haltigan, & Messinger, 2010). Given the speed at which human emotion and behavior can change, some researchers measure facial expressions during each frame of a video recorded interaction (30 frames per second; e.g., Ekas, Haltigan, & Messinger, 2013). Statistical software programs were also developed to meet the computing required by such intensive data. For example, Bakeman and Quera's (1995, 2004) Generalized Sequential Querier (GSQ) was developed to examine transitions between behavior states. Similar to the analyses discussed in earlier paragraphs, this program allows researchers to determine the frequency of the co-occurrence of infant behavioral strategies and changes in infant emotion. In the only known study of infant emotion regulation to use the GSQ program, Crockenberg and Leerkes (2004) examined the regulation of fear in 6-month-old infants. Infants were placed in two fear-eliciting situations in which a novel object (fire truck with a voice, siren, and lights, and a bumble ball) was presented. Mothers were instructed to refrain from interacting with their infant during one situation and were allowed to interact with their infant during the second situation. Infant intensity of emotion was coded continuously using a 7-point scale that incorporated infant facial expressions, body tension, and vocalizations. Change scores were calculated by the GSQ program (Bakeman & Quera, 1995) to determine instances of reduction in negative emotion (i.e., change from a higher to lower intensities of negative emotion), escalation of negative emotion (i.e., change from a lower to higher intensities of negative emotion), and calming (i.e., change from negative emotion to neutral or positive emotion). A variety of putative regulatory strategies, including visual and motor strategies, were also coded continuously. The GSQ program identified each instance of reduction, escalation, and calming within 0.10 s of one of these behavioral strategies. Thus, compared to previous research, GSQ provided greater precision in identifying the confluence of changes in negative emotion and potential regulatory strategies. It is important to note, however, that the analyses of Crockenberg and Leerkes

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(2004) were limited to identifying the co-occurrence of a behavioral strategy and change in negative emotion.

In the same study, when mothers were uninvolved, the behavioral strategies of looking away, self-soothing, and withdrawal were associated with reductions in negative emotion. Looking away from the stimulus and self-soothing were also effective calming strategies. Withdrawal was also associated with increases in negative emotion. Of particular interest, and in support of the suggestions by Cole et al. (2004) for the use of temporal analyses, the correlations between average levels of negative emotion and strategy use differed from the results of the contingency analyses. Looking away and self-soothing were not significantly correlated with overall levels of negative emotion, suggesting they were not serving a regulatory function. However, the results of the contingency analyses suggested otherwise. Thus, in order to accurately identify the behavioral strategies that are responsible for a *change* in negative emotion, the use of analytic techniques that capture temporal ordering is needed.

Although the contingency analyses in these studies improved upon the use of correlation analyses, there are several limitations to the methods that warrant discussion. First, contingency analyses fail to account for the autocorrelation of emotion from one epoch to the next. Often, researchers studying infant emotion regulation are interested in behaviors that occur at a relatively low frequency. The approaches described may not be robust in analyzing infrequently occurring behaviors. There is also some confusion as to whether the contingencies refer to the co-occurrence of the behavioral strategy and change in negative emotion or whether they are measuring whether a behavioral strategy at time t predicts a change in negative emotion from time t to time $t + 1$. The latter is critical to establishing whether a given behavior's strategy is effective at regulating negative emotion. In addition, studies that include temporal sequencing often focus only on a single lag in time. However, it is possible that a given behavioral strategy may not be immediately effective at regulating negative emotion at time $t + 1$, but may be effective at time $t + 2$ or beyond. It may also be particularly informative to determine how long the regulating effect of a given strategy lasts. Another important question that cannot be answered by contingency analyses is the degree of change in intensity of negative emotion. For example, a change from a negative emotion score of 7 to 2 or a change from 5 to 4 would both be considered a reduction. The former example represents a more intense initial state and a more profound regulatory change than the latter. Finally, contingency analyses are unable to test in a single model whether the degree of association between behavioral strategies and negative emotion changes across infancy. In other words, they are not able to examine developmental shifts in regulatory mechanisms. Given the shortcomings of the contingency analysis approach, we recommend that researchers interested in studying the dynamics of infant emotion regulation consider implementing newer techniques such as time-series analyses within multilevel modeling contexts. Such approaches can address critical gaps, and we describe them below.

Examining Temporal Associations Using Multilevel Modeling

Multilevel modeling has emerged as a powerful statistical tool in the study of emotion regulation and has several advantages over other methods. One notable advantage is that multilevel modeling can easily handle missing data and does not require balanced data. This is important because when examining the temporal associations between emotion and behavioral strategies, researchers typically use repeated measures of each variable. For example, a 2 min emotion-eliciting situation may be divided into eight 15 s epochs (e.g., Buss & Goldsmith, 1998) or, as seen in newer research, into 120 1 s intervals (e.g., Ekas et al., 2011). When coding infant emotion and behavior on a second-by-second basis there are likely to be instances of missing data. For example, the infant's face may be temporarily blocked, preventing coding for a short period of time. In some cases, infants may have unequal numbers of observations because the situation was terminated due to excessive distress. Multilevel, or mixed-effects, modeling does not require complete or balanced data to fit a repeated measures model. Multilevel modeling also has the advantage of using all available data from a given individual, rather than relying on listwise deletion of individuals with incomplete data.

With respect to study design, another advantage of multilevel modeling is the ability to use intensively sampled behavior (e.g., second by second, frame by frame) while accounting for the autocorrelation between measurement periods. The decision of time scales (i.e., 1 s intervals vs. longer epochs) should be driven by theoretical considerations, as the upper limit for the number of measurement points for use in typical multilevel modeling is generally constrained only by the researcher's computing capabilities. Although there are no firm rules on the minimum number of measurement points needed, researchers commonly use multilevel modeling with as few as 20 to 30 measurement points (e.g., Thomas et al., 2017).

When analyzing the temporal associations between emotion and behavioral strategies, the primary goal is to determine whether a given strategy is associated with change in emotion. This is consistent with the theme of change that is inherent in the definition of emotion regulation. The previously discussed studies focused on whether or not change occurred; however, the available statistical methodologies were unable to ascertain the *degree* of change or the level from/to which the change occurred. Thompson's (1994) definition of emotion called attention to the importance of the temporal *and* intensive features of emotional reactions. Research using multilevel modeling has recently been able to examine both of these features' aspects in infants (Ekas et al., 2011; Ekas et al., 2013a; MacLean et al., 2014; Thomas et al., 2017). This is because multilevel modeling is a regression-based approach as opposed to the conditional probability approach used in contingency analyses. That is, not only can the question of whether a given strategy is associated with a change in emotion be addressed, but we can also ascertain *how much* change occurs. Multilevel modeling also allows researchers to specify coefficients as random in the models, allowing each individual to have a

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unique estimate for each parameter. Predictors of these individual differences can then be specified. Possible variables that researchers may be interested in include demographic variables (e.g., socioeconomic status), temperament, or attachment, among others. In sum, multilevel modeling provides numerous advantages to the study of infant emotion regulation over previously used methods.

In these multilevel models, the general model specification is that behavioral strategies at time t are hypothesized to affect the change in infant emotion from time t to time $t + 1$. To eliminate the possibility that the lagged effects of behavioral strategies on infant emotion might be due to initial levels of infant emotion (i.e., infant emotion at time t), initial infant emotion is included as a control variable in the model. With the inclusion of the initial level of infant emotion, the dependent variable can be interpreted as residualized change in infant emotion from time t to time $t + 1$ (Kessler & Greenberg, 1981). In addition to testing whether there is immediate change in infant emotion from one interval to the next, researchers can also specify models testing for change at various lags. The use of a given behavioral strategy may not effect immediate change (i.e., within 1 s). Instead, an increase or decrease in levels of infant emotion may not occur for several seconds after a strategy is used by the infant. However, this would be missed if researchers only tested the $t + 1$ lag. Therefore, researchers can specify multiple, separate models of $t + 2$ lags and beyond.

Another advantage of multilevel modeling is that researchers can test whether the effectiveness of a behavioral strategy varies as a function of time. Time could be conceptualized as the elapsed time during the emotion-eliciting situation or it could refer to a larger time scale of chronological age (i.e., in a longitudinal study). A given strategy may not be effective at the beginning of a task situation, but increase in effectiveness as the situation continues. For example, when infants are unable to reach a toy of interest during the toy removal task, self-soothing (e.g., thumb-sucking) may initially decrease levels of negative emotion, but as the situation progresses and becomes more stressful (e.g., they still can't reach their desired toy), this strategy may not reduce negative emotion to the same extent the strategy did earlier in the task. In addition, a given strategy may not be particularly effective at regulating infant emotion at one age but may become more effective as the infant develops or vice versa. Indeed, Stifter and Braungart (1995) found that orientation (i.e., focusing attention on mother or object) was an effective strategy for regulating negative emotion at 5 months of age; however, in separate analyses at 10 months of age, this strategy was no longer associated with changes in negative emotion. Multilevel modeling, however, would allow researchers to use one model to examine whether a behavioral strategy at one moment leads to a change in negative emotion in the following moment and whether the strength of that association changes across infancy. In order to examine the developmental trajectories of these temporal dynamics, a minimum of three time points are needed to test for linear change. In order to formally test for developmental changes, an interaction term between age and the behavioral strategy is specified as a predictor of the change in negative emotion. Below, we describe several studies that have incorporated these techniques.

Ekas and colleagues (2011) were the first to apply multilevel modeling to the study of the temporal associations between behavioral strategies and infant emotion. In this study, 20-month-olds participated in two separate modified Still Face Paradigms with their mother and father. Similar to the traditional Still Face Paradigm, the situation was designed to elicit negative emotion when the parent became unresponsive and the infant was left to attempt to operate a difficult toy. Infant negative emotion and putative regulatory strategies were separately coded on a second-by-second basis. The behavioral strategies included those previously found to be associated with negative emotion, including parent-focused (looking at, vocalizing to, or gesturing to the parent), self-distraction (visual distraction, vocalizing to self, and self-soothing), and stimulus-focused strategies (interacting with stimulus or looking at stimulus). Because this was the first study to use multilevel modeling the study authors explored models with a 1, 2, 3, 4, and 5 s lag. Thus, behavioral strategies at second t were hypothesized to affect change in infant negative emotion from second t to second $t + 1$, second $t + 2$, second $t + 3$, second $t + 4$, and second $t + 5$ in five separate models.

Mother-focused strategies were associated with significant increases in infant negative emotion for 3 consecutive seconds after performing the strategy. That is, separate models in which negative emotion at $t + 1$, $t + 2$, and $t + 3$ were specified as the dependent variable were significant. In this situation, mothers were unable to respond to their infant or to provide any assistance with operating the difficult toy. Therefore, it is possible that the infants became frustrated because their bids for attention were ignored. Self-distraction and stimulus-focused strategies were associated with subsequent declines in the intensity of negative emotion for 1 s and 3 s, respectively. Stimulus-focused strategies, such as focusing on the difficult toy, may provide a distraction from the unresponsive parent because the infant's attention is now occupied by the toy. However, the effectiveness may be relatively short-lived because the toy is too difficult to operate for the infant without assistance. Similarly, self-distraction strategies (e.g., looking around the room) may provide infants with a distraction from both the unresponsive parent and the difficult toy. The longer duration of effectiveness with self-distraction strategies may be because the brightly decorated walls, for example, provide sustained distraction. Some similarities were found with fathers; however, the duration of the effects were shorter. Specifically, father-focused strategies predicted an increase in negative emotion 1 s later, and stimulus-focused strategies were associated with a decrease in negative emotion 1 s later. In contrast to mothers, however, self-distraction strategies with fathers did not lead to changes in negative emotion.

The results of this study highlight dynamics of emotion regulation that may not have been captured in previous models. For example, the degree of change in negative emotion from second to second was relatively small (e.g., 0.03 on a 3-point scale), but could aggregate over multiple seconds. This change in intensity

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Using Multilevel Models to Examine I in Temporal Associations

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may not have been captured in previous studies that required change to be a discrete unit of change (i.e., 3 to 2). The examination of the timing of the temporal effects was also a strength of this study compared to previous methods. For example, some strategies led to changes in negative emotion that lasted for 1 s and others for 3 consecutive seconds. Perhaps the effect of a strategy that lasts for 3 consecutive seconds implies that the strategy is more effective at regulating negative emotion compared to a strategy that only impacts negative emotion for 1 s.

Using a similar statistical approach, MacLean and colleagues (2014) examined the temporal associations between behavioral strategies and emotion in 4-month-old infants who participated in the Still Face Paradigm. Infant emotion and self-soothing behaviors were coded each second of the Still Face Paradigm. The results of the multilevel models indicated that infant emotion became significantly more positive (less negative) following the use of self-soothing behaviors during the still-face episode (in which the parent was unresponsive). These results are consistent with previous research and support the contention that self-soothing is an effective strategy with which infants regulate negative emotion.

Using Multilevel Models to Examine Developmental Changes in Temporal Associations

Although theory and cross-sectional research have contributed to our knowledge about the age at which infants begin using putative regulatory strategies, we know less about their developmental progression. There are few longitudinal studies that investigate *change* in the use of potential regulatory strategies during infancy. In general, infants appear to increase the use of regulatory behaviors across the first 2 years of the life span (Ursache, Blair, Stifter, & Voegtline, 2013). Rothbart and colleagues (1992) found that disengaging attention from a distressing stimulus decreased from 6.5 to 13.5 months of age, whereas shifting attention toward the mother (e.g., social referencing) increased during this same period. Similarly, Braungart-Rieker and Stifter (1996) found decreases in disengaging strategies from 5 to 10 months of age. The ability to voluntarily shift attention is thought to develop between 3 and 6 months of age (Calkins & Hill, 2007). Therefore, it is possible that a decrease in disengagement occurs after 6 months because infants are employing newly acquired strategies. Indeed, 10-month-old infants were more likely to use communicative strategies, such as gesturing, compared to 5-month-old infants (Braungart-Rieker & Stifter, 1996). Consistent with Kopp's (1989) theory, these studies also demonstrate infants' emerging ability to intentionally solicit emotional aid from their caregivers in the period approaching 1 year. In the context of the Still Face Paradigm, several studies have found the use of attentional distraction (e.g., looking away from the unresponsive mother) increases across the first 6 months of life (Moore, Cohn, & Campbell, 2001; Shapiro, Fagen, Prigot, Carroll, & Shalan, 1998; Toda & Fogel, 1993). With respect to self-soothing behaviors, one study found a decrease from 3 to 13.5 months of age

(Rothbart et al., 1992), whereas others found no age-related changes from 3 to 6 months of age (Shapiro et al., 1998; Toda & Fogel, 1993). It is possible that self-soothing is replaced by more sophisticated strategies such as attention distraction by 1 year of age.

There are fewer studies that examine the temporal patterns of emotion regulation at two or more time points during infancy. At 5 months of age, disengaging attention occurred during periods of decreasing negative emotion. However, this effect was not found at 10 months of age (Stifter & Braungart, 1995). Self-soothing behaviors also occurred during periods of decreasing negative emotion, but this effect was only found at 10 months of age. In their cross-sectional study, Buss and Goldsmith (1998) found that attentional distraction was followed by a reduction in negative emotion in 6-, 12-, and 18-month-olds. The results of these two studies suggest there may be developmental differences in the temporal associations between behavioral strategies and infant emotion. However, until recently, longitudinal research utilizing advanced models to capture the developmental trajectories of the temporal dynamics of emotion regulation was missing.

As previously discussed, multilevel modeling allows researchers the flexibility to test a variety of models, including those that can specify age-related changes in the associations between behavioral strategies and change in infant emotion. Ekas and colleagues (2013a), using the same sample as described above, extended their previous study (Ekas et al., 2011) to examine whether the strength of these associations changed across the first year of the life span. Infants participated in separate Still Face Paradigms with their mothers and fathers at 3, 5, and 7 months of age. Infant emotion and behavioral strategies (look at parent, distraction, and self-soothing) were coded each second of the interaction. In this study, the multilevel models tested whether behavioral strategies performed at second t affected the change in negative emotion from second t to second $t + 1$, second $t + 2$, and second $t + 3$. The main effect of age (3, 5, or 7 months) was added as a continuous (coded 0, 1, 2) variable at level 2. Thus, the intercept in this model represented the average level of negative affect at 3 months of age. An interaction between infant age (level 2) and strategy use (level 1) was also specified. The interaction term allowed for the determination of whether associations between strategy use and negative emotion changed across infancy.

Consistent with theory (e.g., Kopp, 1982), we found that the average levels of distraction increased from 3 to 7 months of age whereas levels of looking at the parent and self-soothing decreased during this same period. With fathers, average levels of negative emotion decreased from 3 to 7 months; however, there was no significant change with mothers. Consistent with expectations, distraction was associated with a decrease in subsequent negative emotion with mothers and fathers; however, the magnitude of this effect did not change from 3 to 7 months. This was unexpected given that the ability to flexibly deploy attention improves during the first year and that infants become more sophisticated in their ability to regulate arousal over time (Kopp, 1982). Instead, the effectiveness of this strategy

in reducing negative emotion was present
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Summary and Future Directions in I
Temporal Associations

Emotion regulation is a dynamic proces
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Early research examining infant emotio
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, 1982). Instead, the effectiveness of this strategy

in reducing negative emotion was present at an early age and continued to be effective. Thus, although infants use distractions less frequently when they are younger, its role in regulating negative emotion is relatively consistent during this 4-month period. Self-soothing was also expected to be associated with a decline in negative emotion and the results supported this hypothesis. Although the use of self-soothing declined over time, the effectiveness of this strategy was consistent across age, providing further support for the importance of this behavioral strategy in the regulatory process. It is important to note that this study ended at 7 months of age and it is possible that changes in the magnitude of effectiveness may occur during the second half of the first year and beyond. Indeed, Stifter and Braungart (1995) found that self-soothing was associated with decreasing negative emotion in 10-month-olds but not 5-month-olds. It is possible that the effectiveness of self-soothing may strengthen beyond 7 months of age. Another limitation of the short duration of this study is that it terminated before the onset of major developmental milestones such as crawling or walking. Campos and colleagues (2000) argue that the onset of locomotion brings about changes in multiple domains, including emotions. Specifically, Roben et al. (2012) found increased levels of anger expression after the onset of crawling. Thus, it is possible that the effectiveness of strategies may decline when negative reactivity increases during the latter half of the first year. Nonetheless, this study provides an important step forward in our understanding of the development of the temporal dynamics of infant emotion regulation.

Summary and Future Directions in Research Examining Temporal Associations

Emotion regulation is a dynamic process that involves the coordination of the activated emotion and the behavioral strategies that may change that emotion. Early research examining infant emotion regulation traditionally relied upon a single, global measure of the activated emotion or the behavioral strategies and used those scores to infer whether an infant was regulating their emotions. Conclusions from this body of research suggest that strategies such as visual distraction (i.e., looking away from distressing stimulus) and self-soothing (e.g., thumb sucking) are strategies that are effective at regulating negative emotion. In the past 20 years, researchers have begun to incorporate separate measures of the activated emotion and behavioral strategies to examine their temporal associations. Concurrent advances in statistical modeling (e.g., multilevel modeling) have allowed researchers to answer the critical question of whether the use of a given strategy leads to a *change* in infant emotion.

In several studies, consistent with expectations, the strategy of withdrawing from a novel object was associated with a reduction in negative emotion (Buss & Goldsmith, 1998; Crockenberg & Leerkes, 2004; Diener & Mangelsdorf, 1999). This strategy may be particularly effective in the context of fear because the child's goal is to leave the frightening situation (Buss & Goldsmith, 1998). One strategy that is commonly believed to serve a regulatory function in infancy is attentional distraction. The ability to flexibly deploy attention undergoes a rapid period of development in the latter half of the first year (Calkins & Hill, 2007), and it is believed that shifting attention away from the source of distress reflects developing regulatory capacities (Kopp, 1989). The majority of studies examining temporal associations have found support for this contention, including during fear-eliciting (Crockenberg & Leerkes, 2004) and anger-eliciting tasks (Buss & Goldsmith, 1998; Ekas et al., 2011; Ekas et al., 2013a; Stifter & Braungart, 1995; Thomas et al., 2017). This strategy appears to be effective across a variety of ages ranging from as young as 3 months (Ekas et al., 2013a) to 20 months of age (Ekas et al., 2011). Longitudinal studies also confirm the continued importance of this strategy (Buss & Goldsmith, 1998; Ekas et al., 2013a). Shifting attention away from a source of distress may be effective because it allows infants to take a psychological breather by temporarily focusing on something that is not distressing (colorful posters on the wall, toys in the room, their feet, etc.). Additional longitudinal research across longer periods is needed to better understand how the nature of distraction may be influencing its effectiveness in regulating negative emotion. For example, a brief look away from a source of frustration may be sufficient for a 3-month-old, but a 20-month-old may need to engage with an alternate object for a longer period of time.

The strategy of self-soothing, often consisting of behaviors such as thumb-sucking, has long been believed to serve a comforting function for infants. Early in the first year of life, self-soothing is often a strategy that infants accidentally stumble upon the first time their fingers end up near their mouth. However, infants quickly begin to use this strategy in a purposeful manner (Kopp, 1989). Analyses of the temporal associations between self-soothing and negative emotion confirmed this hypothesis, showing that negative emotion declines after engaging in self-soothing, particularly during the first 7 months of life (Crockenberg & Leerkes, 2004; Ekas et al., 2013a; MacLean et al., 2014).

Although many of the temporal analyses confirmed results from earlier correlational studies, there were several instances in which strategies were not effective at regulating negative emotion. For example, Diener and Mangelsdorf (1999) did not find support for the role of distraction in regulating fear or anger. In addition, self-soothing strategies were not effective at regulating anger among 5-month-old infants (Stifter & Braungart, 1995) or 6-month-old infants (Thomas et al., 2017). These null findings may be due to differences in the characteristics of the study (e.g., emotion-eliciting situation used), infant age, the operational definition of variables, or contextual factors such as whether the parent was involved or uninvolved. Thus, although overall levels of negative emotion and putative regulatory strategies may be correlated, there may not be a temporal association between the two variables. It is also possible that behavioral strategies and changes in negative emotion may occur *together*, but that does not necessarily imply that the strategy is associated with *subsequent* declines in negative emotion.

There are many exciting avenues for this body
continue to conduct studies in which we employ
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There are many exciting avenues for this body of research in the future. As we continue to conduct studies in which we employ intensive longitudinal methodology (i.e., second-by-second or frame-by-frame coding of emotion and behavior), multilevel modeling will likely serve as a statistical tool that can test a variety of hypotheses. Of course, research questions and hypotheses should continue to be informed by emotion regulation theory. One interesting question that merits investigation concerns the timing of strategy use. Across an emotion-eliciting episode, does the effectiveness of a strategy vary? For example, trying to reach a toy behind a barrier may not be associated with increased negative emotion after the first few attempts; however, after repeated attempts are unsuccessful this strategy may be associated with increased distress. Conversely, a strategy such as distraction may be more effective at the beginning of a situation and lose strength as the situation continues. Another important consideration focuses on *when* the strategy is deployed during the emotion regulation process. Is a strategy that is used when the activated emotion is at low intensity more effective compared to during periods of high intensity? The generic timing hypothesis, applied to emotion regulation processes later in the life span, suggests that it is easier to regulate emotions before they reach peak intensity (Sheppes & Gross, 2011). Research is needed to test these hypotheses during infancy.

There are also exciting new statistical models being developed that may capture the dynamics of emotion regulation during infancy. To date, much of the focus has been on identifying emotion regulation strategies and their associations with negative emotion. However, Thompson (1994) also highlighted the importance of understanding multiple features of emotion regulation, including lability. During an emotion-eliciting situation, infant emotion may not change in a linear fashion. For example, during the Still Face Paradigm, infants may not show distress immediately after their parent ceases interaction. Ekas et al. (2013b) found evidence of logarithmic change, such that infants initially began the episode in a nonnegative state, quickly increased in negativity, and then reach an asymptote. However, examination of the raw data suggested that although the average change exhibited a logarithmic increase, there was significant variability around this group pattern. Unexplained variance in the pattern of individual infants may have reflected ebbs and flows in the use of certain behavioral strategies. Using structural equation modeling, Chow and colleagues (2005) formulated a damped oscillator model to capture an individual's emotional lability. Although complex, this model allows researchers to identify an individual's emotional set point (i.e., equilibrium point) and then examine fluctuations in emotion as the individual returns to this set point. This model could be extended in the form of a coupled oscillator model (Boker & Graham, 1998) wherein two process (e.g., emotion and behavioral strategies) can be linked. Indeed, Chow et al. (2010) demonstrate how infant and mother each influence each other's emotional valence, suggesting that such a model could be applied to infant emotional valence and infant regulatory strategies. For instance, negative emotion and attentional distraction may be coupled, such that increases in distraction are followed by decreases in negative emotion. Cole and colleagues (2017) recently applied this modeling to the study of emotion regulation in 36-month-old children and found that children used behavioral strategies during periods of heightened arousal which delayed the increase of subsequent arousal. These models hold great promise for the study of the dynamics of emotion regulation during infancy.

Additional modeling approaches are increasing the scope of possibility for research into emotion regulation. State-space models are another statistical technique that can be used to examine intraindividual change that occurs moment to moment. State-space models are particularly suited for intensive longitudinal designs and may capture the lability of infant's emotional experiences (Chow, Mattson, & Messinger, 2014; Sravish, Tronick, Hollenstein, & Beeghly, 2013). Regime change models allow for the intriguing possibility that the impact of regulatory strategies on emotional processes itself changes over time (Chow, Grimm, Filteau, Dolan, & McArdle, 2013). Another intriguing approach would involve the construction of latent regulatory variables combining various types of behavioral regulation strategies into a single variable. This approach offers the possibility of synthesizing the effects of multiple behavioral regulation strategies at the cost of being unable to distinguish differences between them (Helm, Ram, Cole, & Chow, 2016). Finally, the use of multilevel event history analysis is another possible technique to examine the temporal contingencies between behavioral strategies and emotion. Event history analysis estimates the probability that an event will occur and the factors that might influence that event occurring (Lougheed, Hollenstein, Lichtwarck-Aschoff, & Granic, 2015; Mills, 2011). With respect to infant emotion regulation, researchers could examine the probability of infants transitioning from one emotional state to another within a given time period in response to the use of a given behavioral strategy.

Conclusions

The interest in emotion regulation continues to flourish and great strides in the study of infant emotion regulation have been made since Cole and colleagues' (2004) call to action over a decade ago. Researchers recognize that emotion regulation is not a static entity that can be captured by a single score. Rather, it is a dynamic process that involves the coordination of multiple modalities, namely emotion and regulatory behaviors. Researchers were tasked with ensuring the independent measurement of emotion and behavioral strategies and to capture the temporal associations between these domains. We believe that researchers have begun to meet this challenge as advances in statistical modeling techniques have made it possible to examine *change* in emotion. Using multilevel modeling, for example, researchers have been able to incorporate contingency and time-series models to show that strategies used at one moment in time predict decreases or increases in negative emotion from one moment to the next. Moreover, researchers have also begun to test whether there are developmental changes in the

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direction and strength of these associations. Although much progress has been made in our understanding of emotion regulation during infancy, there is still much work to be done. To that end, we believe that continued examination of the moment-to-moment dynamics of emotion and behavior will be of great value.

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