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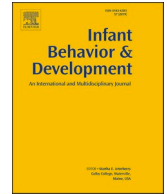
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Early antecedents of emotion differentiation and regulation: Experience tunes the appraisal thresholds of emotional development in infancy

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ABSTRACT

In this review, we synthesize evidence to highlight cognitive appraisal as an important developmental antecedent of individual differences in emotion differentiation and adept emotion regulation. Emotion differentiation is the degree to which emotions are experienced in a nuanced or “granular” way—as specific and separable phenomena. More extensive differentiation is related to positive wellbeing and has emerged as a correlate of emotion regulation skill among adults. We argue that the cognitive appraisal processes that underlie these facets of emotional development are instantiated early in the first year of life and tuned by environmental input and experience. Powerful socializing input in the form of caregivers’ contingent and selective responding to infants’ emotional signals carves and calibrates the infant’s appraisal thresholds for what in their world ought to be noticed, deemed as important or personally meaningful, and responded to (whether and how). These appraisal *thresholds* are thus unique to the individual child despite the ubiquity of the appraisal *process* in emotional responding. This appraisal infrastructure, while plastic and continually informed by experience across the lifespan, likely tunes subsequent emotion differentiation, with implications for children’s emotion regulatory choices and skills. We end with recommendations for future research in this area, including the urgent need for developmental emotion science to investigate the diverse sociocultural contexts in which children’s cognitive appraisals, differentiation of emotions, and regulatory responses are being built across childhood.

I suppose it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail

—Abraham Maslow.

1. Introduction

A necessary but daunting task for developmental emotion science is to clarify the cognition-emotion processes that emerge, transact, and coordinate to support children’s effective and healthy responding to challenge. The cognitive processes and skills that

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support emotional development in early life are myriad—ranging from fundamental perceptual processes to sophisticated understanding of others' unexpressed feelings to the ability to hold multiple contradictory perspectives in mind simultaneously. Emotional development appears to flourish with the emergence of the ability to identify functional similarities across instances and in varied situations (e.g., scowls, widened eyes, and bared teeth, however different in terms of physical presentation, can all function to signal anger: Hoemann et al., 2020). This is thought to allow children to move beyond experiencing what is presumed to be relatively undifferentiated “affect” in infancy (e.g., positive/negative valence, high/low arousal) to experiencing more discrete emotions and emotional events (Hoemann et al., 2019) over developmental time.

The developmental progression of these cognitive processes and how they interrelate with emotional functioning has received tremendous attention among toddlers and preschool age children because of the rapid and dramatic gains in executive functions that can be measured more robustly once children acquire language and are able to exercise representational thought (Barrett, 2017; Fernández-Dols & Russell, 2017; Lindquist & Gendron, 2013). This work has documented that language acquisition provides support for organizing thought, facilitates categorization and concept understanding, and enables broad emotion knowledge to develop. The goal of this review, however, is to introduce a different yet parallel way by which cognition-emotion interactions may support emotional development: through cognitive appraisal processes that underlie emotional development, instantiated early in the first year of life and tuned by environmental input and experience. Appraisals, which are evaluations and judgments about the nature and significance of a phenomenon (Lazarus, 1991), underlie every facet of emotional responding. This can range from noticing perceptual shifts, detecting goal incongruencies, distinguishing between the different emotions one experiences, assessing the necessity and capacity to respond to one's feelings (automatically or effortfully), and implementing a regulatory response. In the coming pages, we delineate cognitive appraisal as a key developmental antecedent of facets of emotional development including emotion differentiation and regulation.

While there is often little consensus about how to define emotion and related phenomena (Ruba & Pollak, 2020), we take a functionalist approach and view emotions as a collection of psychological states that includes subjective experience, expressive behavior (e.g., facial, bodily, verbal), and peripheral physiological responses (e.g., heart rate, respiration) that are flexible, contextually bound, and goal directed (Campos et al., 1994; Gross & Barret, 2011). Under this perspective, emotions are “functional” in part because they provide information about the status (stable, worse, improved) of progress toward one's goals that guides subsequent behavior. Our reasoning is further informed by constructionist models of emotion, which view all mental states as emergent from ongoing, continually modified constructive processes. These models view each discrete emotion as a ‘category’ abstracted from highly variable instances of past experiences (Barrett, 2016). Both functionalist and constructionist approaches place strong emphasis on the role of appraisals and thereby view emotion as an act of meaning making (Gendron & Barrett, 2009). Thus, emotional experience is informed by appraisals of events. These appraisals are calibrated by one's past experiences and can also inform active, constructive processes within the individual to create new emotion concepts, emotional experiences, and other meaning making processes. Because appraisals are unique to each person, they can give rise to variation in the emotional reactions people have to the same event (Lazarus, 1991; Mesquita & Walker, 2003; Scherer et al., 2001). In combining these views, emotion is thus both regulating of (informing individuals about the status of their goals) and regulated by an individual (Gross & Barrett, 2011; Thompson, 2011). Here, we operationalize emotion regulation (ER) as the set of processes by which people influence the emotions they have, when they have them, and how they experience and express them (Cole et al., 2004; Gross, 1998).

2. Emotion differentiation and emotion regulation

In this review, we delineate the evidence for appraisal as an antecedent of an understudied aspect of infants' and toddlers' emotional development, emotion differentiation (ED). In research with adults, emotion differentiation is typically defined as the degree to which someone experiences their emotions in a nuanced or “granular” way—as specific and separate phenomena (Hoemann et al., 2021; Smidt & Suvak, 2015; Tugade et al., 2004). More extensive differentiation is thought to be foundational to positive wellbeing and has emerged as a plausible correlate of ER ability, as people higher in negative ED (e.g., anger vs. disgust) tend to use more ER strategies when compared with people lower in ED (Barrett et al., 2001; Kashdan et al., 2015; Pond et al., 2012). Other work suggests that more extensive differentiation of negative emotions is related to decreased use of maladaptive strategies to manage these feelings (e.g., less use of disengagement strategies intended to escape distressing emotions such as avoidance, distraction, or even alcohol use; Brown et al., 2021). Thus, experiencing more differentiated and specific emotional states may inform the choice and deployment of more precisely tailored regulatory strategies than would be prompted by a more general, less differentiated emotional state (e.g., understanding that one feels *disappointed*, *hurt*, or *frustrated* instead of “bad” gives rise to very different regulatory response options). Thus, ED may play an important role in ER development by providing contextualizing information about whether (and which) ER strategies are needed to meet the specific challenge at hand.

According to this literature, precise differentiation would require some conceptual knowledge of emotion categories as distinct (e.g., sadness is different from fear despite sharing a negative valence; white-hot rage is different from annoyance despite sharing a parent emotion category of anger). Important metacognitive information about the typicality and intensity of the affective experience that would support emotion labeling (e.g., *I am feeling sad, not scared*) and evaluation (e.g., *how typical is this feeling for me?*) may also be available to the individual. For instance, experiencing rage when one's anger typically maxes out at annoyance would mark that eliciting context as particularly salient and might prompt the choice of a less frequently used regulatory tool or strategy to manage it. Of course, infants do not yet possess such conceptual knowledge or metacognitive capabilities, so the potential utility of ED for guiding regulatory choices in early life is unknown.

While previous work has advanced our understanding of ED in adult samples, less is known about the *developmental* antecedents of

ED and its implications for ER. Studying emotional experiences in infancy and toddlerhood is constrained by substantial methodological and conceptual challenges (see Ruba & Pollak, 2020). In studies with adults and older children, researchers rely on the use of self-reports of subjective feeling states to quantify differentiation. Measurement in younger samples remains complicated by the fact that infants and young toddlers are less capable of labeling and describing their own emotions than are older children and adults. Indeed, almost nothing is currently known about the cognition-emotion interactions specific to infancy and toddlerhood that represent the developmental origins of ED and its possible links to ER.

We posit that a key cognitive process implicated in the development of ED is *appraisal*. We argue that the developing appraisal process is calibrated, in part, by the unique proximal emotion socialization dynamics between caregivers and infants that shape person-specific appraisal thresholds (e.g., *What is this? Does it matter to me? Can I handle it? How so?*). The emotional information provided to infants from birth via social interactions contains a profound wealth of information about the reliability of caregivers in meeting the infant's needs, the type and intensity of emotional signal (e.g., distress cry) that will be contingently responded to (and how), the types of emotions that are typically communicated, valued, and expressed within the family or home context, and more. Infants are remarkably good at distilling relevant information from their environments and social partners. These proximal socialization processes continually transact with the accumulation of experience, further supporting the eventual understanding of which emotions need to be identified, experienced, responded to, and otherwise "known" in an individual's social world. Not every affective state is prioritized in each environmental context, whether different cultures, regions, or even families introduce the constraint. This dynamic tuning creates individualized appraisal thresholds, which set the stage for children's emotion differentiation, emotion regulation, and other aspects of emotional development in early life.

2.1. Infants' emotion responding indexes underlying appraisals

Methods of assessing emotional development in preverbal infancy vary widely (e.g., exposure to positive and negative facial expressions, intermodal studies across emotions of different valence, social referencing, event-emotion matching). These approaches largely tend to assess infants' abilities to notice, identify, and interpret others' emotional expressions and reactions (Denham, 1986; Ogren & Johnson, 2020), rather than measure differentiation in the infant's own emotional experiences per se (see Stenberg et al., 1983, for an exception). As such, we view this corner of the emotion development literature as providing evidence for infants' developing appraisal thresholds: what in their world ought to be noticed, deemed to be important or personally meaningful, and responded to (whether and how).

2.1.1. Responding to perceptual input

Infants develop concepts of emotion in part based on categorization of perceptual features that coincide with distinct expressions of emotion (e.g., sad faces have downturned smiles, sad speech tends to be slower) (Barrett et al., 2007; Ekman & Friesen, 1975). Given their salience for survival, the ability to discriminate between different kinds of emotional signals has been argued to be evidence of a core emotion understanding ability (Ruba & Repacholi, 2020). Research that leverages habituation and/or looking time paradigms indicates that young infants show changes in responding when presented with different stereotyped facial configurations (both between- and within-valence). For example, by the time infants are five months old they can discriminate sad from fearful facial configurations and angry from sad and fearful facial configurations (although only when previously habituated to stimuli showing angry stimuli; Schwartz et al., 1985). By seven months, infant looking times also indicate an attentional preference for fearful over happy expressions (Geangu et al., 2016; Krol et al., 2015; LoBue & DeLoache, 2010), and these attentional biases are accompanied by greater heart rate deceleration in response to fearful faces (Leppänen & Nelson, 2009; Peltola et al., 2011; Peltola et al., 2009). Although findings are mixed, some ERP data suggest that 7-month-old infants show different Nc amplitudes when observing happy compared to fearful expressions (Jessen & Grossmann, 2015, 2017; Taylor-Colls & Pasco Fearon, 2015). Taken together, this research indicates that infants notice and respond to differences in discrete facial emotional stimuli, suggesting that they appraise these phenomena to be meaningfully distinct.

2.1.2. Social referencing in emotional contexts

There is also work that indexes infants' varied responding to discrete emotion contexts based on their social referencing behavior. Social referencing, the use of other people's reactions to a situation to inform one's own understanding of that situation (Feinman et al., 1992; Walden & Ogan, 1988; Walle et al., 2017), is a way for infants to gather additional contextualizing information from other people to inform their appraisals of the salience or relevance of an event. For example, 10- to 24-month-old infants alter their behavioral responses to a situation based on the facial expressions of an agent (e.g., making appraisals based on social referencing to guide behavior). If an agent makes a happy face in response to an object, infants are much more likely to approach or touch the object, but infants will avoid the object if the agent makes a fearful face (Kim & Kwak, 2011; Kim et al., 2010). Infants also alter their behavior across evocative contexts of similar valence (as opposed to between-valence contexts previously mentioned). For example, in a study with 16-, 19- and 24-month-old infants, participants were shown two instances of an agent reacting with expressions of either joy, sadness, fear, anger, or disgust. Results showed that 24-month-old infants were more likely to avoid the agent after they displayed anger than when they displayed the other negative emotions (Walle et al., 2017). Further, the 24-month-olds were almost twice as likely to demonstrate security seeking behaviors (e.g., retreating to the caregiver to seek or ask for comfort, checking in behaviors such as looking or vocalizing towards the caregiver with the goal to feel safe) when observing expressions of anger and disgust than when observing sadness. Finally, 24- and 19-month-old infants were least likely to explore a stimulus when they observed expressions of disgust toward the stimulus, compared to other observed emotion expressions. This work suggests that infants incorporate contextual

information sourced from other people into their appraisals of event salience and relevance.

2.1.3. Awareness of goal congruence

Outside of the domain of emotion, research on infants' understanding and predictions of goal-directed actions indicates that context-specific appraisals (e.g., of the relevance of an event for one's goals) develop relatively early on, as infants as young as six months of age demonstrate understanding of goal-directed actions. After habituating to a goal-directed action, they will look longer at an action done in the service of achieving a different goal than to an action that suggests a different approach to achieving the same goal (Woodward, 1998). By eight months, infants distinguish goal-relevant from goal-irrelevant information presented to them while observing performance of an action to infer the intended goal (Hamlin et al., 2009; Woodward, 1998). By 10 months, infants appear capable of anticipating an actor's goal, even when it is not achieved (e.g., putting a ring on a cone, Brandone et al., 2014).

As emotions provide information about the status of one's goals, goal-congruency paradigms have also been used to assess infants' understanding of emotion. This understanding is propelled by experiences with their own and others' emotions in social contexts (see Walle & Campos, 2012 and Reschke et al., 2017a for reviews). Infants demonstrate knowledge that other peoples' emotions are tied to their experiences—and those experiences can affect the status of someone else's goals. For example, infants understand that persistent goal-directed behavior may be important to attend to even in the absence of contextualizing emotion (Premack & Premack, 1994). By 18 months, infants imitate failed actions that are repeatedly performed by a researcher, indicating an awareness of the intention to complete the actions even in the context of repeated failure to do so (Meltzoff, 1995). Reschke and colleagues extended Meltzoff's study by investigating how an agent's emotion signals may influence 15- and 18-month-old infants' re-enactments of the agent's intended actions (2020). They found that infants re-enacted more of the intended interactions in the context of a frustrated experimenter (than a neutral one), but that this effect was stronger among the 18-month-old infants—suggesting that the emotional signals provided more disambiguation of the experimenter's goal in the situation, thus facilitating infants' understanding and re-enactment of the experimenter's intentions. Other work illustrates infants' sensitivity to mismatch in others' emotional expressions as indicating an understanding of emotions as meaningful signals of the relational processes between people, their goals, and their current environments (Chiarella & Poulin-Dubois, 2013; Hepach & Westermann, 2013). Thus, research on understanding and prediction of goal-directed behavior indicates that infants may make context-specific appraisals of the relevance of an event for someone's goals, and this also influences their own behaviors and goals (Reschke et al., 2020).

2.1.4. Responses to violated expectations

Researchers have also provided evidence for infants' appraisals of differences between discrete emotion categories by leveraging studies of their violation of expectations about which facial configurations should be tied to specific events. Infants are presented with evocative video clips of an event, then shown a stereotyped facial configuration that either does or does not align with the intended evoked emotion of the event. This work suggested that after watching a character attain a known goal (learned via familiarization trials), 8- and 10-month-old infants generally expected to see the character show positive facial expressions but not negative ones (although this pattern was replicated only for the older age group when a slightly different type of goal was implemented; Skerry & Spelke, 2014). Furthermore, longer looking times to an unexpected facial configuration (one that misaligns with the event, e.g., a happy face shown in response to an event that was intended to evoke disappointment) also suggest by 10 months of age, infants were sensitive to mismatch and exhibited different attention patterns based on whether an actor's expressive responses to achieving or failing to achieve a goal violated expected emotional reactions (Skerry & Spelke, 2014). Similarly, 10- and 14-month-old infants have shown greater sympathetic nervous system activation (indexed via pupil dilation) when presented with an angry actor performing a "happy action" (e.g., petting a plush animal) than when seeing the same angry actor perform an "angry action" (e.g., thumping/hitting the plush animal), but only 14-month-olds were similarly sensitive to a happy actor performing an "angry action" (Hepach & Westermann, 2013). Looking past happy vs. angry comparisons, a study of 12-month-olds demonstrated that infants did not expect expressions of sadness over anger after another individual broke an agent's toy but did expect happiness over anger or sadness when a toy was gifted (Reschke et al., 2017b). In another study with older infants, 14- and 18-month-olds expected expressions of anger (over disgust or fear) after a failed goal and expected disgust (over anger or fear) after eating a novel food (Ruba et al., 2019).

Expectancy violation research also supports the presumption that preverbal infants can make basic appraisals about emotion-relevant situations. For example, Scherer and colleagues (2004) examined infant responses to novel situations in which expectations were violated across a sample of 5-, 7-, 9-, 11–12, and 14-month-old infants. After playing with an experimenter for a short period of time, infants observed a sudden and unexpected change in the experimenter's voice quality (increased sharpness), creating both a novel and unexpected emotion context. Nine-month-old infants, but not 7- or 5-month-old infants demonstrated reliable patterns of behavioral freezing and changes in gaze direction in response to this expectancy violation which suggests a developmental change in the capacity for evaluating novel/surprising events. Interestingly, researchers did not observe changes in infants' facial configurations in response to violation of expectations (e.g., they did not show surprise when expectations were violated). Given their differential responding to surprising and unsurprising stimuli presentation, this research on violation of expectancy suggests that infants notice and appraise differences between discrete emotion categories.

2.1.5. Summary

In sum, we argue that this body of work, despite not explicitly focusing on infants' appraisal processes, provides compelling evidence that infants' emotion responding indexes underlying appraisal components including noticing, deeming to be meaningful/important, and responding. This literature suggests that infants make predictions about human behavior, and in particular event-emotion associations, based on their appraisals (e.g., *What is this? What does it mean for someone's goal?*) and expectations of what

ought to happen. From a very young age, infants are sensitive to differences between discrete emotion categories and to mismatches between antecedent events and people's subsequent reactions; indeed, infants' responding aligns with the appraisal of these experiences as noteworthy and relevant. This suggests that even before language and representational thought enable more rapid gains in emotion understanding, cognition-emotion interactions are implicated in preverbal infants' emotional development.

A possible explanation for how facets of emotional development like ED and ER develop is via the cognitive appraisal process that is being calibrated in infancy. A functionalist perspective holds that appraisals provide critical information underlying responding ranging from emotional reactivity to regulatory processes (see Scherer, 2018 for a review). Appraisals of novelty (*what is this?*), intrinsic pleasantness (*is this good?*), goal congruence (*what does this mean for my goals?*), and resources or ability to cope (*if necessary, do I have the ER skills to handle this?*) guide subsequent behavioral responding. These evaluations support infants' development of differentiated emotional experiences and responding in combination with bottom-up biological processes like temperament, synchrony, and physiological responding (important to be sure, but beyond the scope of this review). Appraisal processes would thus underpin emotional responding to different emotion contexts and input, including the extent to which emotions are differentiated and subjectively experienced, and how they are ultimately managed or regulated. In the next section, we consider how these intrapersonal appraisal processes are shaped via interpersonal socialization and experiential tuning.

3. Experiential tuning of the appraisal processes that antecede emotion differentiation and regulation

As reviewed above, differential responding to different emotion categories and contexts is generally present in early infancy. One of the most vexing challenges in studying the development of appraisal processes is the inability to directly observe or assess mental states and functions. Furthermore, infants (unlike older children and adults) are unable to label or provide narrative insight into their subjective emotional experiences outside of their behavioral reactions. Changes in their overt emotionally expressive behaviors (e.g., behavioral freezing and gaze allocation in response to expectation violation among older infants), however, provide some insight into the developmental progression of cognitive appraisals (e.g., Scherer & Ekman, 2014). An open question in developmental science is how the appraisal process originates and develops from a phenomenon characterized by responding to interpersonal/external stimuli to one characterized by noticing, evaluating, and responding to one's own intrapersonal experiences. Empirical evidence is slim, but we suggest that it develops dynamically through repeated transactions with people comprising the infant's social world. In our view, appraisals must be precisely calibrated to serve individual children in their unique environments—thus the thresholding for each appraisal component (*What is this? Does it matter? Can I handle it? How so?*) must be tuned for individuals in early life. These thresholds are then continually calibrated through experiences over developmental time as the cognitive infrastructure for increasingly sophisticated kinds of appraisals is constructed (thanks to advances in language, theory of mind, concept development, and emotion category formation, among others).

3.1. Socialization tunes infants' cognitive appraisal thresholds

Infants are exquisitely adept at learning what they need to be able to do in their environments, including what sorts of emotional responses and action tendencies would have utility in their specific social worlds. From birth, rich emotion-related information is communicated to infants, including how their caregivers will respond to various emotional expressions (and how quickly, reliably, or well). This prepares infants to glean information about the extent to which more extensive differentiation of emotions is useful (and necessary) in their world over time. If some distress signals are met with non-response or dismissiveness but others receive encouragement, full caregiver attention, and soothing, infants receive information about which expressions will be noticed and taken seriously—this in turn will progressively shape their understanding of those emotion signals.

Contingent responding to some infant cues and not others thus marks certain emotional experiences and contexts as salient and worthy of attention or further processing (Brophy-Herb et al., 2011; Havighurst et al., 2022). General emotional expressiveness in children's home environments has also been linked to emotional understanding (Ogren & Johnson, 2021), though the effects seem to be focused on the primary caregiver's emotional functioning (e.g., impulsive emotional responding) rather than the general expressiveness in the family. This supports our point that parents would, through their own emotional responding and modeling, mark certain emotion-related responses as especially salient over others. Because parents and families vary widely in their typical responses to children's emotional cues, the input children receive about emotion is hyper-individualized and tailored by the caregiver's beliefs, values, and goals about emotion—all of which infuse their contingent responding (Meyer et al., 2014; Rosenblum et al., 2006). In support of this, research has found that infants of parents who typically engage in greater expressive suppression were more likely to detect when an experimenter masked her disgust, likely due to increased experience being exposed to such masking displays more often when interacting with their parents (Walle & Campos, 2014). Research also supports the idea that children from more expressive families are more expressive themselves (Halberstadt & Eaton, 2002) but that the effects of expressivity can vary by valence and across time. For example, children from families that are more expressive of positive emotions are also more expressive of their own positive emotions and more accurate at recognizing others' expressions of positive emotion (Dunsmore & Smullen, 2001; Halberstadt et al., 1999). For global (overall) and negative-submissive (sadness, fear) expressiveness, however, family expressiveness has been related to poorer emotion understanding later, when these children reach college-going age (Halberstadt & Eaton, 2002). Thus, the long-term implications of family emotional expressiveness for children's emotions are not fully understood, and more research is needed on this topic.

Even without perfect fidelity or consistency in caregivers' emotional responsiveness, infants can discern patterns when they occur with statistical regularity in their environments (Plate et al., 2022). Of note, contingent responding to infants' emotional signals should

calibrate the most basic forms of appraisal—including noticing an event (detecting novelty) and assessing whether it is good (if not, is it ignorable?). In terms of infants' soliciting social support and parental responsiveness in infancy, contingent responding shapes what sorts of feelings and contexts are meaningful and understood to merit a response from others in the environment. This marks for the child the experiences that meet the (appraisal) threshold for communicated emotional response for that specific child in that specific family, and potentially serves as a mechanism by which external (interpersonal) information becomes internalized (intrapersonal) over time and repeated experience. The more nuanced the caregiver responding is, across time and *between and within* discrete emotion contexts, the greater differentiation of emotional experience the child is likely to acquire (Mesman et al., 2012).

Learning what to attend to in different emotion contexts is another skill that is shaped by caregivers and may promote ED. A study by Knothe and Walle (2018) examined parents' talk about various discrete emotion contexts with their 18- and 24-month-old children. They found that parents emphasized different aspects of the situational context depending on the emotion being discussed. Specifically, parents referenced the person having the feeling (the "emoter") more in the contexts of anger and sadness but referenced the target of the feeling (the "referent") more often when discussing disgust and fear (Knothe & Walle, 2018). This differential emphasis on specific aspects of discrete emotion contexts is another example of the many ways emotion socialization processes continue to influence children's differentiation in toddlerhood, as parents increase mental state talk in the second year of life (Ornaghi et al., 2019).

In sum, the progressive shaping of children's appraisal thresholds begins in early infancy and proceeds across the first years of life. Basic appraisal components, of what an event is and what it means for an individual, support emotion differentiation. Equally important for our understanding of children's emotion development more broadly, however, is the question of how appraisal (and differentiation) may relate to the emotion regulatory processes in which children engage.

3.2. Implications of appraisal thresholds for emotion regulation strategy use

One of the more advanced components of appraisal is the determination of whether one has the resources and ability to cope with the matter at hand. This facet of appraisal is also tuned by experience, including cues from the external environment as well as the subjective experience of one's own feelings. It has direct implications for ER, including general responses to challenge, seeking support from caregivers, and eventual autonomous regulation in the form of strategy selection and deployment.

A recent investigation of the links between maternal responsiveness and toddlers' ER strategy behaviors in the United Kingdom and Italy provides initial evidence for the power of socio-culturally calibrated early appraisal and ED processes that relate to different ER strategy approaches (Bozicevic et al., 2021). This study considered maternal responsiveness in the context of mothers' valuing of different forms of emotional expressiveness (e.g., more positive affect and sociability in the Italian sample; more even-keeled emotional tone in the UK). Parents' emotion-related beliefs and values, conveyed to their infants over time, was related to different appraisal processes for children in these two cultural contexts. The longitudinal design employed in this investigation enabled initial assessment of dyads in face-to-face interaction when infants were two months old and the same children's ER in response to frustration (a barrier task) when they were 24 months old. The infants' emotion expressive behaviors were already differentiated in line with parents' emotional values at two months of age—Italian infants smiled more whereas UK infants engaged in more pre-verbalizing vocalizations. General and culture-specific relations were found, with greater maternal responsiveness in early infancy associating with better 24-month ER *overall*. With regards to the *specific ER strategies* children used to manage frustration, however, there were cultural differences. UK children relied more on communicative ER strategies (designed to elicit social support and help from others), whereas Italian children exhibited more self-reliant strategies like shifting attention and distraction. This longitudinal study suggests that socialization processes influence appraisals not only of the types of emotional expressions that are understood to be appropriate, but also help to calibrate developing individual differences in how emotions are managed. Socialization processes and culture thus influence developing appraisals of what types of responses are more appropriate or expected, and what types of ER strategies may best be applied when distressed.

Additional cognitive skills, developing across the first years and beyond, undoubtedly support the more advanced components of appraisal, such as assessments of whether and how one can cope with the situation. As one selected example, enhancements in effortful control, a main dimension of temperament that reflects the ability to voluntarily regulate behavior (e.g., inhibitory control) and attention in the service of broader goals, seem to underlie advances in self-regulation, including ER, across the second and third years of life (Gagne, 2017; Gagne et al., 2021; Rothbart & Rueda, 2005). In the first few months of life, infants' attention is automatically directed toward stimuli in the environment that is salient, but from nine to 18 months of age, the ability to control attention and direct it toward stimuli or objects that are aligned with their own goals rapidly improves. This skill coincides with developmental advances in planned, purposeful action and the ability to resolve conflicts when processing information (Posner & Rothbart, 1998; Ruff & Rothbart, 1996).

There is also ample evidence that the purposeful control of attention serves as one of the earliest voluntary forms of ER. At 13 months, infants can disengage their attention from an evocative stimulus; this attentional disengagement coincides with decreases in emotional reactivity, suggesting regulation through effortful attentional control (Rothbart, Ziaie, & O'Boyle, 1992). Thus, on a basic level this indicates that appraising a situation as salient or evocative can be followed by a volitional regulatory response. Across the 24- to 48-months period, young children demonstrate increasingly reliable patterns of controlling their visual attention toward objects they prefer, which coincide with their decision making (e.g., the gaze-bias effect). For example, when presented with a forced-choice task to select from two options, young toddlers will more often direct their gaze toward an object that reflects their preference or "choice" even before making their selection and reaching for the object (Saito et al., 2020; Valkenburg & Cantor, 2001). The number of eye gazes towards the preferred option increases across this developmental window, co-occurring with increases in the effortful control of attention and behavioral inhibition. By 30 months of age, infants demonstrate the ability to coordinate shifts in attention with

inhibition of behavior to support a goal (Posner & Rothbart, 1998). Furthermore, advances in the effortful control of attention and inhibition of behavior from 22- to 33-months coincide with the ability to control anger (Kochanska et al., 2000). Notably absent from the current literature is research linking these gains in cognitive skills to sophistication in appraisal, emotion differentiation, and emotion regulation decision making.

3.3. Implications of emotion differentiation for emotion regulation

Because ED arguably filters the range of emotional experiences and subsequent response options and opportunities for ER, differentiation calibrates the possible regulatory responses, including implicit and explicit tendencies and processes like strategy selection, flexibility, and optimization. As an “upstream” (early-on) part of the appraisal process, ED provides enhanced nuance and granularity about the possible evaluations of incoming input and experience. It can lead to better specification of what something means for the individual (“I lost my toy and am disappointed,” rather than a cruder appraisal like, “something bad happened, and I feel bad”). This calibrates the experience and understanding of an event, guiding “downstream” (later in the appraisal process) regulatory responses. To illustrate this, take the example of children’s understanding of and adherence to sociocultural display rules for when and how emotions should be expressed versus suppressed (e.g., Denham, 2007). In the second year, 15- and 18-month-old infants demonstrate alignment with display rule expectations by managing emotions in the service of expected behavior in social contexts (Repacholi et al., 2014). Other work has linked emotion knowledge to toddlers’ general emotion regulatory skill, demonstrating that observed emotion knowledge positively correlates with ER skills, even when accounting for general language ability (Ornaghi et al., 2019). By toddlerhood, the consequences of this early appraisal tuning for emotion regulatory behaviors are already evident. Indeed, studies have shown that toddlers’ overgeneralization of fearfulness to low threat contexts – indicating less nuanced appraisals of the potential threat and emotion differentiation – prompts an overreliance on avoidance behaviors and dysregulated physiological responding (e.g., Buss, 2011; Buss et al., 2018).

As the cognitive infrastructure of appraisals continues to develop in childhood, further nuance in how ED guides subsequent ER, including explicit use of ER strategies, may emerge. ER strategies provide a repertoire of tools for emotion management that can be known, selected, deployed, optimized to fit to the demands of the eliciting context, monitored for effectiveness, and flexibly abandoned and replaced with other strategies as needed over the course of an emotional challenge. Emotion differentiation, though a relatively new idea in research focusing on early childhood, may be one of the most crucial elements of emotion knowledge that develops in the first years of life because of how it parses the regulatory options when choosing from the toolbox—in other words, emotion differentiation helps the individual choose from an appropriately curated set of tools (strategies) to complete the job. Less differentiation, in contrast, would mean less nuance in understanding what is felt and thus, potentially less adept selection of ER strategies that are likely to work efficiently in the given context.

To harken back to the quote from Abraham Maslow with which we opened the paper, less differentiation would mean that every emotional experience is a nail. If emotion differentiation filters the toolbox of ER strategies as we suggest, nothing but a hammer would ever be available to choose to manage one’s feelings. More extensive emotion differentiation, in contrast, paints the world and one’s experiences in richer and more nuanced shades: *this* may be a nail that I need to hammer down, but *this* is a splinter protruding from my finger that I need to carefully extract. The latter appraisal would highlight different tools that could be chosen from to complete the task (e.g., tweezers or pliers instead of a hammer). The functional and adaptive selection of the right tools for the job—an ER strategy or strategies that align with the individual’s regulatory goal—may thus be gated by individual differences in emotion differentiation.

In sum, we have highlighted the case for the developing appraisal process in infancy being a key cognitive precursor of ED and ER. The components of the appraisal process are tuned by social experiences from the first months of life in service of the unique needs of an individual child. The developing appraisal thresholds for what kinds of emotional information ought to be noticed and acted on form the foundation of individual differences in emotion differentiation. Though more evidence is needed to support the links we hypothesize here, the precision in ER strategy calibration that may be afforded by greater emotion differentiation is an important direction for future developmental research.

4. Recommendations for future research

Although the literature we have reviewed provides compelling initial evidence that appraisal processes underlie many facets of emotional development, including ED and ER, it also reveals several gaps in knowledge that limit scientific understanding of the development of these cognition-emotion connections. We focus our discussion here on a select number of directions for work in cognition-emotion interactions across development as a suggested starting point.

4.1. Sociocultural contexts

First, it is vital that developmental emotion scientists consider the sociocultural contexts that tune cognition-emotion interactions in infancy and toddlerhood. We have assembled an argument for infants’ relationships with caregivers as representing an immediate, proximal context in which children’s appraisal calibration takes place. Of course, individual children are embedded in multiple, layered social contexts subsuming their relationships with caregivers, including with other family members, peers, their neighborhood and community, society broadly, and the cultural and historical time contexts (Bronfenbrenner, 1986). These relational contexts of development would theoretically titrate emotional expression and experience in support of adaptive functioning within the individual child’s unique experiential context; knowledge in this field would benefit from increased attention to the diverse sociocultural contexts

in which children's knowledge of emotions, their appraisals of emotion contexts, and appropriate responses to them are being built together across childhood.

4.2. Methodological innovation

Second, assessing cognitive and emotional processes is notoriously difficult. Most of this research relies on behavior in early life, which means scientists must infer underlying states that cannot be directly observed. Furthermore, the variation in methodologies used in prior work makes it difficult to directly compare performance across ages and document developmental change (e.g., Ruba & Repacholi, 2020). Most of this research compares performance across positive and negative emotion conditions, limiting the inferences that can be made about infants' more nuanced emotion understanding and appraisals. For example, there is less research exploring infants' ability to discriminate within-valence comparisons (see Walle et al., 2017 for an exception), and thus there is a continuing need for studies that investigate infants' responding to discrete emotion contexts within emotions of a similar valence and level of arousal (e.g., fear and anger; Ruba & Repacholi, 2020). Even better would be approaches that comprehensively capture a range of infant responses to different types of emotion inputs across early development (e.g., vocalizations in addition to facial expressions, behaviors, manipulation of environment).

Expanding our methodological toolboxes from single assessments to multi-method, multi-modal approaches is critically necessary to move beyond incremental gains in knowledge of how emotion understanding is shaped in infancy. Studies that rely on capturing responses across a single modality (e.g., looking times or facial expression alone) are often limited in the conclusions that can be drawn and may not capture key components of infant emotion understanding sophistication (Ruba & Repacholi, 2020; Scherer et al., 2004). Relatedly, the important role that infant temperament has been shown to play in shaping emotional experiences in early life highlights the need for greater inclusion of psychophysiological and neurobiological methodologies (Buss, 2011; Buss et al., 2018) in future studies examining appraisal, ED, and ER. We need to leverage multi-modal assessments that can capture responses across several indices (e.g., physiology, facial expressions, approach/avoidance behaviors, vocalizations).

More broadly, challenges remain in how to assess ED and appraisals in early childhood, ER strategy-related choice and decision making, and the underlying processes that support the development of these skills in ecologically valid ways. Studies with adults have used ecological momentary assessments to capture real-time emotion differentiation (Hoemann et al., 2021; Kalokerinos et al., 2019). Infant research has used ambulatory audio devices to capture the full spectrum of linguistic input infants are receiving for months before they begin to produce words—applying a similar approach to capturing the emotion-related input that shapes and tunes appraisals, ED, and ER in infancy would be a fruitful next step (Lopez et al., 2020; Pretzer et al., 2019; Tsai et al., 2007).

Once multi-method streams of emotion-relevant input are captured, these could be integrated with contextualizing data about caregiver beliefs about emotion and socialization practices. This would support the possibility of leveraging computational and statistical learning models to advance understanding of what processes drive developmental and within-infant changes in emotion differentiation and ER, which can be critical to understanding different trajectories of mental health and wellbeing across the lifespan (Meyer et al., 2014). For example, whether and how language and the linguistic diversity of children's environments underlies differences in emotion knowledge that relate to children's acquisition of emotion concepts and ER strategy use remains understudied and is a fruitful avenue of exploration (see Ogren & Sandhofer, 2022). The links between expressive vocabulary and social-emotional competencies in young children suggest that the broader array of vocabulary words that are available to bilingual children might introduce conceptual infrastructure for differentiating between emotions and improving knowledge about emotion-related contexts highlighting language as a needed area of emphasis in developmental studies of emotion-cognition connections (Ornaghi et al., 2019; Streubel et al., 2020).

4.3. Identification of links between ED and well-being

Finally, despite growing interest in this topic in the broader psychological literature, the precise links between ED and ER remain unknown. ED appears to support decreased self-reported use of strategies that carry negative health consequences (e.g., binge drinking, Brown et al., 2021) but limited studies have linked ED to more specific ER strategy selection and implementation. Past work does suggest that having poor ED is linked to greater initiation of ER strategies, suggesting that poorly defined emotional experiences are associated with less effective ER (Kalokerinos et al., 2019). And, we have argued that ED may serve to filter or gate the available set of ER strategies from which to choose. It is clear that we need to better understand how and why ED relates to ER and emotional wellbeing. How children's developing appraisal thresholds shape emotional development is a critical piece of this puzzle. Unpacking these associations in infancy and childhood will clarify which cognition-emotion processes are shaping patterns, trajectories, and alterations in responding to challenges across development.

5. Conclusion

In this review, we synthesized and evaluated evidence that cognitive appraisal is an important antecedent of emotion differentiation and adept emotion regulation. The tendency to experience one's own emotions with a high degree of differentiation is supported by developing appraisals in infancy and toddlerhood that are dynamically shaped through social interactions. This socialization input calibrates the infant's appraisal thresholds for what aspects of their experience ought to be attended to, deemed to be salient or personally meaningful, and responded to (whether and how). These appraisal *thresholds* are thus unique to the individual despite the ubiquity of the appraisal *process* in emotional responding. The early calibration of the appraisal infrastructure, while plastic and

informed by experience across the lifespan, likely influences subsequent emotion differentiation and regulatory skills. As these links are fully investigated in future research, they will contribute new insight to developmental science about how cognition and emotion interrelate.

CRedit authorship contribution statement

Elizabeth L. Davis: Conceptualization, Writing – original draft, Writing – review & editing, Supervision. **Parisa Parsafar:** Conceptualization, Writing – original draft, Writing – review & editing. **Shannon M. Brady:** Writing – review & editing.

Data availability

No data was used for the research described in the article.

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