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Emotion Words, Emotion Concepts, and Emotional Development in Children: A Constructionist Hypothesis

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Abstract

In this paper, we integrate two constructionist approaches – the theory of constructed emotion and rational constructivism – to introduce several novel hypotheses for understanding emotional development. We first discuss the hypothesis that emotion categories are abstract and conceptual, whose instances share a goal-based function in a particular context but are highly variable in their affective, physical, and perceptual features. Next, we discuss the possibility that emotional development is the process of developing emotion concepts, and that emotion words may be a critical part of this process. We hypothesize that infants and children learn emotion categories the way they learn other abstract conceptual categories – by observing others use the same emotion word to label highly variable events. Finally, we hypothesize that emotional development can be understood as a concept construction problem: a child becomes capable of experiencing and perceiving emotion only when her brain develops the capacity to assemble ad hoc, situated emotion concepts for the purposes of guiding behavior and giving meaning to sensory inputs. Specifically, we offer a predictive processing account of emotional development.

Keywords

prediction, construction, variation, social learning, culture

Scientists continue to debate the nature of emotional development. Does it refer to the formation of emotion concepts that are scaffolded onto inborn or early-developing emotional capacities (Izard, 1997; Izard, Woodburn, & Finlon, 2010)? Emotional development, in this view, refers mainly to the ability to regulate innate, universal emotional reactions. Or are children born with undifferentiated affective sentiments such as distress, pleasure, quiet attention, high arousal, and sleepiness, such that emotional development refers to the process by which children carve affect into differentiated emotional responses (e.g., Bridges, 1932; Camras, 1992; Matias & Cohn, 1993; Oster, Hegley, & Nagel, 1992)? In this latter view, children learn to experience and perceive emotions in culture-specific ways, so as to be maximally effective at eliciting responses from their caregivers (Holodynski & Friedlmeier, 2006; Weiss & Nurcombe, 1992; Werner, 1948). Empirical studies have been unable to settle the matter, with scientists drawing divergent conclusions, sometimes from the same data. This lack of resolution may be rooted in a deeper concern: both perspectives assume that instances of an emotion category such as *anger* are relatively similar in their physical and perceptual features. Similarly, both perspectives assume that emotion concept development means acquiring a representation to be stored in memory, as a set of necessary and sufficient features, a prototype, or an intuitive theory. In this paper, we question both assumptions and in doing so introduce a novel theoretical framework for guiding research on emotional development.

Our approach integrates two constructionist approaches: the theory of constructed emotion and rational constructivism (Barrett, 2017a, 2017b; Lindquist, 2013; see Box 1). The theory of constructed emotion itself integrates social constructionist (e.g., Averill, 1980; De Leersnyder, Boiger, & Mesquita, 2013; Vygotsky, 1934/1987) and psychological constructionist views of emotion (e.g., Cunningham, Dunfield, & Stillman, 2013; James, 1894; Russell, 2003) with a predictive coding approach to brain structure and function that provides an intrinsically constructionist account of the mind and behavior (Barrett, 2017b; Barrett & Satpute, 2017; Barrett & Simmons, 2015; Chanes & Barrett, 2016). The theory also incorporates discoveries from cognitive science (e.g., Barsalou, 2008), linguistics (e.g., Vigliocco, Meteyard, Andrews, & Kousta, 2009), anthropology (e.g., Lutz, 1983), human evolutionary biology (e.g., Boyd, Richerson, & Henrich, 2011), and evolutionary/developmental neuroscience (e.g., Barrett & Finlay, in press). The basic hypothesis is that emotional events derive from an active, constructive process within the brain. The brain starts with current conditions and creates an ad hoc, embodied concept, reinstating prior experiences that are similar to the present. In this way, a brain is continuously assembling prediction signals that prepare the body for situation-specific action, creating perceptions and experiences.

Rational constructivism is a theory of cognitive development that compliments the theory of constructed emotion in creating a scientific framework for studying emotional development. It suggests that human infants begin with a set of proto-conceptual primitives, and the end state of concept development is best characterized by a set of domain-specific intuitive theories. Furthermore, three types of domain-general learning mechanisms account for development and conceptual change: (a) language and symbol learning, which changes the format of representation of the proto-conceptual primitives; (b) Bayesian inductive learning, which provides a principled and rational way for belief revision, by taking into account both prior knowledge and input statistics; (c) constructive thinking mechanisms such as explanation, analogy, mental imagery, and thought experiment, which allow the learner to build new representational primitives and new theories that may be incommensurable with old theories (for reviews, see Fedyk & Xu, 2018; Gopnik & Wellman, 2012; Xu, 2016; Xu & Kushnir, 2012, 2013).

[Box 1 near here]

Using this framework, we suggest that the science of emotional development largely shares a set of assumptions about the nature of emotion categories and concepts that may not be warranted by the available empirical evidence. Instead, evidence is consistent with the hypothesis that emotion categories are abstract, conceptual categories, whose instances are situated and therefore highly variable in their features. Accordingly, we hypothesize that emotional development begins with identifying functional similarities across instances in a given situation that need not share observable similarities. Functional similarity is established based on shared purpose: children must learn that a variety of instances involving different bodily sensations and actions are in the service of the same context-specific goal. Sometimes this goal is physiological (e.g., to gain warmth), sometimes it is concrete (e.g., to get a hug), sometimes it is psychological (e.g., to feel safe with someone). By learning to impose a functional similarity on instances that vary in their physical, perceptual, and psychological features, children move from experiencing affect (the mental counterpart of bodily sensation, with properties of valence and arousal) to constructing emotional events (specific instances of affect that are linked to the immediate situation and involve intentions to act).

Next, we hypothesize that children learn emotion categories the way that they learn other abstract, conceptual categories: with the help of words spoken by caregivers and other humans around them. Specifically, we hypothesize that infants and children observe others using emotion words to label events of affective, physical, and perceptual change, inviting them to learn that instances in which sights, smells, sounds, and behaviors differ can serve the same goal-based function in a given situation. As a child's brain learns emotion concepts, it develops the capability to construct emotion categories in a situated fashion, thereby guiding action and making sensations and affective feelings meaningful in a given situation. Finally, we propose that children acquire the capacity to experience and perceive the emotions of their culture via this language-guided concept learning within their social relationships.

To begin this paper, we review major theoretical viewpoints on the nature of emotion categories, and offer evidence to support our hypothesis that emotion categories are abstract, conceptual categories that are constructed in a situated way. We then propose that emotion words help infants and young children learn emotion concepts. We also offer a targeted review of studies to illustrate the plausibility of our hypothesis that emotion words are a powerful tool for the cultural transmission of emotion concepts. Finally, we end the paper by proposing that as a child's brain develops emotion concepts, she also becomes capable of emotional experience and emotion perception. In this predictive processing account, concepts are ad hoc, goal-based constructions that serve to make emotional meaning of sensory inputs. That is, in our view, emotion development is tantamount to emotion concept development.

Emotion Concepts and Categories

An instance of any category can be described by a set of features. An instance of emotion is an event described by physical features (e.g., patterns of facial movements, vocal acoustics, autonomic nervous system changes, neural activity), affective features that capture what the instance feels like (e.g., how pleasant or unpleasant it feels, how arousing it feels; Barrett & Bliss-Moreau, 2009; Russell & Barrett, 1999), perceptual features (i.e., the sights, sounds, smells, and so on, that occur), appraisal features that refer to how the situation is experienced (e.g., whether the situation is novel or familiar, conducive to one's immediate goals or not, and so on; Barrett, Mesquita, Ochsner, & Gross, 2007; Clore & Ortony, 2008; Clore & Ortony, 2013) and functional features that refer to the goals that a person is attempting to meet (e.g., to avoid a predator, to get closer to someone, to win a competition, etc.; e.g., Adolphs, 2017; Lazarus, 1993). An emotion category is a grouping of emotional instances that have some feature or set of features in common. Many debates about the nature of emotion, including the nature of emotion in infants and young children, boil down to disagreements about which features are similar and the degree of variation in the relevant features in the instances of a given emotion category. (For a more detailed review, see Figure S1 of Barrett, Adolphs, Marsella, Martinez, & Pollak, forthcoming.) .

In emotion research, some scientists have described emotion categories as natural kind or classical categories, whose instances share a common set of physical features across situations (large within-category similarity/small within-category variation). Correspondingly, instances of different categories are supposed to be distinguishable from one another by their different features (small between-category similarity/large between-category variation). In this view, emotion categories are assumed to have firm boundaries in nature – to cut nature at its joints. It has been proposed, for example, that infants are endowed with the innate capacity to express certain categories of emotion with diagnostic, invariant facial movements (e.g., Izard et al., 1995; Izard, Hembree, Dougherty, & Spizzirri, 1983; Izard, Hembree, & Huebner, 1987; Lewis, Ramsay, & Sullivan, 2006). If an emotion category has a classical structure, then its corresponding concept reads like a dictionary definition that is stored in memory, describing its necessary and sufficient features.

Other scientists have argued that emotion categories are prototype categories, whose instances have some family resemblance or degree of typicality. Each instance is thought to contain a sample of the features that might describe the category, resulting in more within-category variation and more between-category similarity than for a classical category. An emotion category's corresponding emotion concept (its prototype) might be its most frequent instance or its most typical instance (i.e., the instance that has the largest number of the category's distinguishing features; e.g., Russell, 1991). Or it might be a theory that describes the most typical instance (e.g., Clore & Ortony, 1991). A number of theoretical approaches hypothesize that emotion categories are structured as prototype categories (basic emotion approach, e.g., Ekman & Cordaro, 2011; psychological construction approach, e.g., Russell, 2003; appraisal approach, e.g., Shaver, Schwartz, Kirson, & O'Connor, 1987). In the study of emotional development, it has been proposed that instances of the same emotion category may vary in their physical features, but share a common goal-based function (e.g., Campos, Campos, & Barrett, 1989; Campos, Mumme, Kermoian, & Campos, 1994) that derives from evaluating (or appraising; Lazarus, 1991) the situation in a particular way. For example, instances of the same emotion category (e.g., anger) might serve the same goal-based function across various situations (e.g., overcoming an obstacle), as long as the situations are experienced as having the same meaning. However, different autonomic nervous system changes, facial movements, bodily movements, and other physical features may be used to achieve that goal in different situations.

More recently, it has been proposed that emotion categories are abstract, conceptual categories, whose instances share a common goal-based function within a specific situation, but whose features (including the goal) can vary widely from situation to situation (Barrett, 2006, 2012, 2013, 2017a, 2017b; Barrett, Wilson-Mendenhall, & Barsalou, 2015; Lebois, Wilson-

Mendenhall, Simmons, Barrett, & Barsalou, 2018; Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011). The hypothesis is that emotion categories, like all abstract, conceptual categories, do not have a core set of context-independent features (Barrett et al., 2015; Wilson-Mendenhall et al., 2011). Unlike the typological thinking that supports classical and prototype categories, the notion of conceptual categories (Barsalou, 1983, 1985, 2008; Barsalou, Simmons, Barbey, & Wilson, 2003) is rooted in population thinking – the idea that a biological category is populated with context-dependent, variable instances, so that any summary of the category (like a prototype) is a statistical abstraction that need not exist in nature (Darwin, 1859/2003; Mayr, 2004). In this view, the representation of a category (i.e., its concept) is itself situation-dependent, and represents the instance that best meets a specific goal or serves a specific goal-based function in a given situation, even if the instance does not actually exist in nature (e.g., Barsalou, 1993; Voorspoels, Vanpaemel, & Storms, 2011). Correspondingly, the hypothesis is that the similarity shared by instances of an emotion category is not fixed or static; it varies from situation to situation because the category itself is not fixed but is constructed by the brain in an ad hoc, situationally specific manner. In everyday life, such flexibility allows a brain to draw boundaries between what is the same and what is different, not in absolute terms, but with reference to a particular goal-based function in a particular situation (Barrett, 2017a; Barsalou, 1985).

Empirical Evidence of Emotions as Abstract, Conceptual Categories

Major meta-analyses are consistent with the hypothesis that emotion categories are abstract, conceptual categories, giving evidence of substantial feature variation within categories as well as similarity across categories. A recent meta-analysis revealed that autonomic nervous system features are highly variable across experimental contexts, showing neither consistency nor specificity for each emotion category (Siegel et al., 2018). Meta-analyses of brain imaging studies (e.g., Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012) show a similar result, as do brain imaging studies using pattern classifiers (e.g., compare the findings from Kragel & LaBar, 2015; Saarimäki et al., 2016; for additional discussion, see Clark-Polner et al., 2017). These findings are echoed by analyses of brain networks (Raz et al., 2016; Touroutoglou, 2015) and single neuron recordings (Guillory & Bujarski, 2014), all of which support the hypothesis that an emotion category shows context-dependent variation in its neural features.

Studies of facial muscle movement during emotional events replicate findings from the body and brain. A comprehensive narrative review found that adults express instances of the same emotion category with more variable, context-dependent facial movements than is generally assumed, and frequently use similar facial movements to communicate a variety of different emotion categories (Barrett et al., forthcoming). Even within a given culture, people often do more than scowl when angry, frown when sad, and smile when happy. There are no published studies of how people across cultures spontaneously express emotions in the face, but the available evidence from studies of emotion perception shows that there is considerable cross-cultural variation in the emotions that people infer in each other's facial movements (Gendron, Crivelli, & Barrett, 2018).[1] The evidence for how infants and children move their faces during emotional instances is strongly consistent with these conclusions. Young children begin to express emotions with the adult-like facial movements after the first year of life (Camras, Castro, Halberstadt, & Shuster, 2017; Camras, Fatani, Fraumeni, & Shuster, 2016; Camras & Shutter, 2010; Oster, 2005), and, like adults, heterogeneity persists (e.g., Camras et al., 2007; Matias & Cohn, 1993). For example, infants and young children do not consistently scowl in situations thought to evoke anger, but they routinely scowl when crying, for whatever reason (Camras et al., 2016). This variation and lack of specificity is observed in studies of older children, as well (e.g., Camras et al., 2017).

Emerging evidence suggests that instances of an emotion category vary in their psychological features in much the same way as they vary in their physical features. Brain imaging evidence indicates that affective features like valence (pleasantness/unpleasantness) and arousal (Barrett & Bliss-Moreau, 2009; Russell, 2003) vary in a context-dependent way within an emotion category (Wilson-Mendenhall, Barrett, & Barsalou, 2013; Wilson-Mendenhall, Barrett, & Barsalou, 2015). Unpleasantness can be experienced during instances of happiness, and pleasantness can be experienced during instances of *fear, anger,* and *sadness*. Categories vary in their appraisal features (Kuppens & Tong, 2010), which describe how people experience the situation during an emotional event (Barrett, Mesquita, et al., 2007; Clore & Ortony, 2008). Even the goal associated with instances of an emotion category varies by context. For example, instances of anger can be associated with the goal to overcome an obstacle (particularly when the obstacle is another person), to protect against a threat, to signal social dominance or appear powerful, to affiliate and repair social connections, to enhance performance to win a competition or a negotiation, or to enhance self-insight (e.g., Ceulemans, Kuppens, & Mechelen, 2012; De Rivera, 1981; Van Kleef & Côté, 2007).

Taken together, then, studies demonstrate the robust and replicable finding that emotion categories are characterized by large within-category variation as well as between-category similarity in their physical and perceptual features. Evidence further suggests that instances of emotion belonging to the same category can vary in their affective and psychological features. This sort of variation appears to be the norm, rather than the exception.[2]

Children's Emotion Concepts

It is commonly assumed that infants have emotion concepts by about six months of age, as evidenced by their ability to discriminate between posed facial configurations that are stereotypes of facial expressions *anger, sadness, fear,* and *happiness* categories (e.g., smiling faces to depict happiness, scowling faces to depict anger: Haviland & Lelwica, 1987; Izard, 1994; Izard et al., 2010; Walker-Andrews, 2005). However, most published studies actually assess infants' ability to distinguish the physical features of the stereotypes, the novelty of the stereotypes, or the affective features that describe the facial configurations, such as valence and arousal, and do not include the necessary controls to conclude that infants are actually perceiving exemplars of distinct emotion categories. Importantly, everyday facial movements are far more variable than the category stereotypes (Barrett et al., forthcoming). Because emotion categories such as *anger*, *happiness*, *pride*, and *fear* are populated with instances that vary in their physical and psychological features, emotion concept learning requires that children make inferences about functional similarities across these variable instances. This realization may help explain why, to date, there is no strong evidence that infants are born with emotion concepts, despite persistent beliefs to the contrary.

Research shows that by three to four months of age, infants possess rudimentary concepts for pleasantness and unpleasantness (Flom & Bahrick, 2007). These affect concepts begin with multimodal perceptual features: infants at this age do not distinguish positive from negative in faces that are presented without additional information, such as accompanying vocalizations (Walker-Andrews, 1997), and do not clearly distinguish different modalities of information until four to six months of age (Walker-Andrews & Lennon, 1991). Such findings contradict the assumptions that facial movements are focal in the development of emotion concepts (e.g., Denham, 1998; Harris, 1994; Harris, de Rosnay, & Pons, 2016), and that investigations of emotion development should center on how well infants perceive posed, static stereotypes of facial expressions. Using facial stimuli, alone, infants do not show evidence of affect concepts until five to seven months of age, when they consistently distinguish pleasant, smiling faces (posing the stereotypic expression of *happiness*) from those posing unpleasantness (scowls, pouts, etc.), but still do not differentiate stereotyped expressions for negative emotion categories (e.g., Leppänen & Nelson, 2009). Although five- and seven-month-olds have been shown to discriminate between frowning faces (depicting *sadness*) and scowling faces (depicting *anger*; Soken & Pick, 1999) or gasping faces (depicting *fear*; Schwartz, Izard, & Ansul, 1985), these faces can be distinguished by their differing arousal features (low vs. high). That is, by this age, infants have unimodal concepts for the perceptual features associated with valence and arousal, but not necessarily for emotion categories (i.e., *anger, sadness*, and *fear*; Barrett et al., forthcoming). The psychological features of infants' early affect concepts – in particular, how they understand or what functional similarities they associate with their experiences – have not been well examined.

The first strong evidence for distinct emotion concepts can be seen in young children, between the ages of two and three, who explicitly infer emotional meaning in facial configurations when asked to categorize them with emotion words (more than a dozen studies are reviewed in Widen, 2016; see Figure 1). These studies, too, suffer from the limitation that they use stereotyped expressions and do not test children's emotion concepts using instances that are more variable in their features. As we review next, however, research has shown that young infants can learn abstract categories with the help of words. Based on this evidence, we hypothesize that it is possible – even likely – that infants begin to learn emotion concepts much earlier than they can explicitly label facial configurations with emotion words.

[Figure 1 near here]

A Constructionist Proposal for Emotional Development

A brain is constantly faced with continuous sensory inputs such as dynamically changing wavelengths of light, air pressure, chemical concentrations, and so on, which are noisy and ambiguous in their meaning. Where emotions are concerned, infants' learning environment is rich in highly variable, multimodal cues. The relevant data for their learning are changing over time: the sensations from their own body, the representations of their own motor actions, the sound of their own voice, as well as the movements and vocal acoustics of the people around them. To make sensory inputs meaningful, a brain asks, "What are these similar to"? Somehow, the infant must learn which events are functionally similar and which are distinct, even as the perceptual regularities provide little guidance.

A growing body of research suggests that words help infants to learn context-dependent, conceptual categories whose exemplars share abstract similarities (Gelman & Roberts, 2017). Correspondingly, we hypothesize that in the first two years of life, there may be a tight dependence between the emotion words that caregivers naturally use when labeling an infant's actions, affect, and/or motivational goals as emotional instances and an infant's ability to impose goal-based, functional similarities on physically variable instances. That is, the emotion words that are a natural part of an infant's social environment may direct the cultural inheritance of emotion categories and the corresponding culture-dependent concepts. This process may sometimes proceed with explicit labeling (e.g., "Look at that pout! You're feeling angry right now!"). But, more often than not, infants merely observe their caregivers in their incidental use of emotion words (e.g., “Don’t cry. Don’t be angry, sweetie” or, when talking to another adult, “I was so angry, I could have cried!”). As infants hear their parents and caregivers using emotion words, these may serve as scaffolds for imposing similarities on physically different instances (or imposing differences on physically similar instances). Words may thereby encourage infants to assemble emotion categories and use the corresponding concepts to experience and perceive emotion (for discussion of hypotheses, see Barrett, 2017a; Barrett, Lindquist, & Gendron, 2007; Lindquist & Gendron, 2013; Lindquist, MacCormack, & Shablack, 2015).

Currently, there are few comprehensive studies of emotion words in speech directed at or used around infants and very young children, but those that exist show that young children’s use of emotion words covaries with their mothers’ (e.g., Dunn, Brown, & Beardsall, 1991) and predicts their understanding of others’ emotions (Wellman, Harris, Banerjee, & Sinclair, 1995). Recent evidence is likewise consistent with the hypothesis that caregivers’ use of mentalizing words predicts their young children’s mentalizing abilities (e.g., Ensor, Devine, Marks, & Hughes, 2014; Ruffman, Puri, Galloway, Su, & Taumoepeau, 2018). In addition, there is substantial evidence that words speed concept development more broadly. Much of this research focuses on the development of object categories, but we hypothesize that these findings may also provide clues to how infants and young children begin to learn emotion categories.

The Role of Words in Concept Development

Studies in the last two decades have shown that words serve as invitations to form categories (Balaban & Waxman, 1997; Perszyk & Waxman, 2018; Waxman & Markow, 1995; Xu, 2002, 2007, 2016; Xu & Carey, 1996; Xu & Tenenbaum, 2007). For example, when infants as young as six months are presented with a word (‘blicket’) while viewing a set of variably shaped objects of the same category (e.g., dinosaurs), they show a novelty preference for a new object from a different category (e.g., fish). This effect suggests that infants are able to use the presence of the word to form a category and, compellingly, is not observed when tones are used instead of words (Fulkerson & Waxman, 2007; Waxman & Leddon, 2010; see Ferry, Hespos, & Waxman, 2010, 2013 for very early developmental changes). These findings suggest that words may foster concept development by encouraging infants to identify similarities in exemplars, thereby learning a category.

Objects have many features, and words help learners decipher which features are important for categorizing in a given situation. By labeling objects with the same word, parents and caregivers encourage children to compare features (Gentner, 2010; Gentner & Medina, 1998). This process of comparison makes perceptually similar objects appear more similar (by allowing children to background or ignore less relevant features), and makes dissimilar objects appear less similar (by foregrounding features that vary), thereby sharpening category boundaries (Boroditsky, 2007). Naming also helps preserve these category boundaries by drawing attention to (and potentially reifying) the set of similar and dissimilar features derived from the process of comparison (Gentner, 2003; Lupyan, Rakison, & McClelland, 2007). In fact, words that are correlated with physical features (e.g., material, shape) enhance children's learning of categories defined by those features (Yoshida & Smith, 2005). In everyday life, this might mean that an infant will learn that small, four legged animals with short-thick fur and long-silky fur, who purr, are associated with the word 'cat'. The word 'cat' helps the infant learn that the animals belong to the same category by generalizing across the concrete instances, foregrounding certain features (four legs and a tail, purring) and ignoring others (type of fur).

Words may be helpful for learning categories whose instances have physical features with some statistical regularities, such as concrete objects, but they may be critical for learning abstract categories whose instances share fewer regularities. That is, words may allow infants to transcend their immediate perceptual experiences to form conceptual categories (Waxman & Gelman, 2010) – such as emotion categories (Barrett, 2012) – that are based on situation-specific goals. Conceptual categories are an example of social reality: instances of a category are similar to one another, not because they share physical features, but because a group of people impose a similar function on them by collective agreement (Searle, 1995). While the instances of object categories can also be similar in their functional features (e.g., a *chair* is any object that can be used for sitting in a given situation), the instances of conceptual categories are linked only by their context-dependent functional similarity. By encouraging statistical learning (Aslin, 2017) and/or reinforcement learning (Atzil, Gao, Fradkin, & Barrett, 2018; Barrett, 2017a), words may support infants' ability to impose functional similarities on objects, actions, and events that are perceptually dissimilar.

Many creative experiments suggest that words encourage infants and young children to form abstract, conceptual categories. In a typical study, an experimenter shows an object to two groups of infants, calling it by a made up name ('blork') for one group, while the second group hears no name. The object is then revealed to rattle when shaken, and is presented to the infants along with other objects, some of which also rattle (i.e., objects share the function 'to rattle'). Infants who hear the word form the category *rattling objects* regardless of the objects' physical appearance. Infants who are not exposed to the word only form the category *rattling objects* when the objects are perceptually similar (Graham, Kilbreath, & Welder, 2004; Welder & Graham, 2006). Young learners expect perceptually different objects that share the same label to also share the same nonobvious properties (Baldwin & Markman, 1989; Dewar & Xu, 2007, 2009; Welder & Graham, 2006), such as the role or function that an agent serves, suggesting that infants can learn labels as easily for concepts associated with abstract goals as for objects identified by perceptual features (e.g., Yin & Csibra, 2015). Words then allow learners to expand a category (i.e., perform induction) by adding novel items (Gopnik & Sobel, 2000), and to treat perceptually identical items as functionally distinct (Dewar & Xu, 2009; Study 3, Feigenson & Halberda, 2008). Conversely, labeling perceptually identical objects with different words allow infants to carve them into different categories (e.g., Feigenson & Halberda, 2008).

The potency of words for concept learning can also be seen in infants' acquisition of superordinate categories (e.g., *vehicles, animals*), which are difficult to learn given that instances share fewer physical features. When 13-month-old infants are given a common word to describe a set of objects from different basic-level categories, they successfully form a superordinate-level category (Waxman & Markow, 1995). When an object from one category is morphed into an object from another category, infants and preschoolers who hear one label for all the familiarization instances form a single category, whereas those who hear two labels form two categories (Addyman & Mareschal, 2010; Althaus & Westermann, 2016; Havy & Waxman, 2016; Landau & Shipley, 2001; Plunkett, Hu, & Cohen, 2008).

For infants, then, words play a critical role in aiding and shaping concept development (Gelman, 2003; Gelman & Waxman, 2009; Xu, 2007, 2016; Xu & Tenenbaum, 2007). Words may act as a kind of conceptual glue by virtue of their own perceptual features (phonemes, i.e., sounds). When a caregiver labels an object, action, or event for an infant, the word becomes part of the multimodal pattern that the infant learns. Words' referential meaning may, in fact, be rooted in the way its perceptual features become embedded in temporal sequences of sensations and actions, along with the other things that infants learn about caregivers, like intentions and preferences (e.g., Bonawitz & Shafto, 2016). This may be one explanation for why 12-month-old infants seem to understand that people use speech to communicate their internal mental states such as beliefs, desires, and goals (Vouloumanos, Onishi, & Pogue, 2012). Consequently, a word may be an opportunity for imposing higher-order regularities, as it is associated with a pattern of sensory and motor changes in a specific situation.

For children, merely observing other people use the same words across different situations, with different constellations of features, may be sufficient for learning abstract concepts, particularly if those people are confident experts with some status or prestige. Research suggests that young children can use cues for degree of skill or competence to select who they observe and socially reference (e.g., Birch, Akmal, & Frampton, 2010; Corriveau & Harris, 2009; Koenig & Harris, 2005; Sabbagh & Baldwin, 2001; Scofield & Behrend, 2008). Evolutionary biologists have suggested that this type of observational learning underpins one of our major adaptations as a species – culture (Henrich, 2015). Nonetheless, for very young infants, words alone may not be sufficient to invite the development of abstract concepts. Some communicative intent may be necessary to indicate a word's referential status (Balaban & Waxman, 1997; Campbell & Namy, 2003; Fulkerson & Haaf, 2003; Jaswal, 2004; Namy & Waxman, 2000). Even nonlinguistic sounds can support concept development if they are intentionally offered as a label for objects when interacting with an infant (e.g., Ferry et al., 2013; Fulkerson & Haaf, 2003; Namy & Waxman, 1998, 2000, 2002). Intent allows infants to harness the conceptual power of words, to organize the world in ways that are consistent, meaningful, and predictable, particularly in relation to other people.

Emotion Words and the Development of Emotion Concepts

We hypothesize that infants and young children learn emotion categories in much the same way that they learn other abstract, conceptual categories whose instances differ in their features from situation to situation: with the help of relevant words. Specifically, we hypothesize that parents and caregivers begin to curate an infant's emotional life by sometimes labeling events with emotion words. For example, the western category of *anger* is associated with many goals, one of which involves overcoming an obstacle that someone blameworthy has put in your path. So, when one infant takes a toy away from another, sometimes she will cry, and her parents or caregivers might label this instance as 'anger'. Sometimes, the infant might swat the other child, and, again, her parents or caregivers might label this instance as 'anger'. When the infant spits her food out, or tips a bowl onto the floor, these events might also be labeled as 'anger'. So too when her play is interrupted to get ready for bed, and she stiffens her body as she is picked up. In each situation, the different motor actions are accompanied by different facial movements, different changes in the systems of her body (to support her motor actions) and correspondingly different bodily sensations, different sights, sounds, actions by adults, and so on, but they are all associated with the same goal: to remove an obstruction put there by someone else. We hypothesize that, across these dynamic, multimodal patterns, she also occasionally hears her parents uttering the word 'angry'. Instances of word usage may be sparse at first (in particular, those directed at the infant; e.g., Beeghly, Bretherton, & Mervis, 1986; Dunn, Bretherton, & Munn, 1987), but may help to agglomerate the category over time.

Our hypothesis, then, is that emotion concepts develop via the same mechanisms as the other concepts that children learn. Language's role in concept development is not unique to emotion, but may be particularly important for the acquisition of abstract, conceptual categories, such as emotion categories, that do not show strong statistical regularities in their physical features. Language is likely only one set of symbols that can help infants and young children learn to treat diverse instances as similar for some goal-based function, but we suggest that it is a consistent and pervasive one that continues to have influence throughout the lifespan. Whether spoken or written, words allow the members of a culture to dynamically re-establish category boundaries by labeling instances, reinforcing the social reality that they create. Through dialog during social interaction, people come to use the same words to categorize objects, actions, and events, progressively aligning the associated concepts (e.g., Brennan & Clark, 1996). This may be one mechanism by which people communicate emotion (Gendron & Barrett, 2018) and help to co-construct each other's emotional experiences (Barrett, 2017a). For infants, this process of co-construction begins before they are able to participate verbally. Nonetheless, even if an infant cannot explicitly speak emotion words, the capacity for her brain to construct emotion concepts in a situated fashion may be a prerequisite for experiencing and perceiving the emotions of her culture. That the social and linguistic context of emotional development are a formative influence on infants' brains is not a new proposal (e.g., Campos et al., 1989; Ratner, 1989; Trevarthen, 1984). The novel aspect of our framework derives from a predictive processing account of brain function within the theory of constructed emotion, as we describe next.

Emotion Concepts and the Construction of Emotional Events

There is an emerging consensus in developmental neuroscience that a newborn brain is not a miniature adult brain (e.g., Dubois et al., 2014): an infant's interactions with the wider world around her – including other people and the words they speak – function as a set of instructions for her brain to wire itself to the physical and social conditions of her environment, a process that takes more than two decades to complete. The suggestion is not that newborn brains are a tabula rasa (e.g., newborn brains most likely come wired for affect; e.g., Bridges, 1932; Camras, 1992; Matias & Cohn, 1993; Oster et al., 1992; Sroufe, 1997). Nonetheless, infant brains must learn some very basic functions, including to regulate the body (Sterling, 2012). This development places bodily regulation (including movement) at the core of all mental function (Barrett & Simmons, 2015), including much of concept development (Atzil et al., 2018). We hypothesize that much of this development is relevant to embraining emotion concepts, wiring a brain with the capacity to experience and perceive emotions.

A Predictive Processing Account of Brain Function

From birth onwards, the brain has to continually solve reverse inference problems: it must guess at the causes of sensory inputs so it knows what actions to take next, while (encased in a skull) only having access to the effects. Any given sensory input, such as a flash of light or an ache in the body, can have many different causes. Brains have evolved to efficiently solve these reverse inference problems by functioning as an internal model of the system that generates the sensory inputs – its body in the world. A brain learns the multimodal patterns of sensory inputs from its body (interoceptive and somatosensory) and the world (light, vibrations, chemicals, etc.) and these patterns can be reinstated for later use (Polyn, Natu, Cohen, & Norman, 2005). Moreover, the brain is thought to reinstate these patterns predictively rather than reactively, to actively infer the causes of sensory inputs from the body and the world (e.g., Friston, 2010; Sterling & Laughlin, 2015; Wolpert, Diedrichsen, & Flanagan, 2011).

This account of brain function is variously referred to as predictive coding (A. Clark, 2013), active inference (Friston, 2010; Friston, FitzGerald, Rigoli, Schwartenbeck, & Pezzulo, 2017), belief propagation (Lochmann & Deneve, 2011), or the Bayesian brain (Vilares & Kording, 2011).[3] These approaches, while different from one another, all share a core hypothesis: a brain starts with initial conditions in the body and the world and predicts forward in time, anticipating what the body has to do next. These prediction signals prepare the body to make some set of movements (Wolpert, Pearson, & Ghez, 2013), anticipating the body's energy needs to support these movements and attempting to meet those needs before they arise (e.g., through visceromotor changes in the autonomic nervous system, immune, and endocrine systems), thereby maintaining physiological efficiency (Sterling, 2012). Predictions help to create the experiences that the brain ultimately constructs: the neurons that prepare visceromotor changes and motor actions also send collateral information to neurons in the brain's sensory systems. These copies are thought to modulate the ongoing firing of sensory neurons, inferring the sensory consequences of those movements, thereby simulating some future state of the body and the world (e.g., visual, acoustic, olfactory, gustatory, tactile, and interoceptive sensations). This prediction is then either confirmed or corrected by sensory inputs from the body and the world as they reach the brain.

The Role of Concepts in Prediction

We propose that 'concepts' are another name for the brain's predictions (i.e., its internal model), such that a brain solves its reverse inference problem by concept construction. By reinstating prior experiences to anticipate the possible causes of sensory inputs, the brain is attempting to answer the question, "what past experiences are the expected sensory inputs most similar to?" (Bar, 2009). When predicting forward in time, a brain does not construct one signal but an entire array, each of which has some probability (a prior probability) of being similar to the upcoming sensory inputs for a situation-specific purpose. Namely, these signals represent the possible causal relationships between events in the world and the body as they are right now, and their sensory and motor consequences in a moment from now. As such, we hypothesize that, in running an internal model and generating predictions, the brain is continually constructing ad hoc, embodied concepts (Barsalou et al., 2003; Casasanto & Lupyan, 2015) to guide action and meet the context-specific goal (Barsalou, 1991, 2003) of efficient physiological regulation (Barrett, 2017a; 2017b).

Following Bayesian logic (Bastos et al., 2012; Deneve, 2008), the prediction with the strongest prior probability might be confirmed by sensory inputs from the world and the body (Gallivan, Logan, Wolpert, & Flanagan, 2016). If errors of prediction occur – that is, unanticipated sensory inputs arrive to the brain – the brain has an opportunity to update itself (i.e., to learn), so that the internal model can predict more efficiently and with less error in the future. Once a prediction is confirmed, sensations are explained (Lochmann & Deneve, 2011) – we would say categorized – so that the brain understands what caused them and how to act to deal with them, making them meaningful. From this perspective, meaning making involves knowing how to act, and predictively estimating the body's energy needs for that action.

We hypothesize that this continuous, dynamic process of generating predictions while resolving prediction error explains how a human brain constructs the experience of emotion in oneself, or a perception of emotion in someone else (Barrett, 2017a; 2017b; see Figure 2). We propose that when a brain generates a group of prediction signals using past emotional events (i.e., sensations and actions that were made meaningful as emotional events), it is generating an ad-hoc emotion concept. This ad hoc emotion concept is a brain's best guess as to what will cause incoming sensory changes, and what visceromotor changes and motor actions are required to deal with that causal occurrence. Once a prediction is confirmed, then sensations are categorized as an emotion, and the brain understand the emotion as having caused the actions and the visceromotor changes in the body. This is how, for example, a scowl may come to serve as an expression of *anger, concentration, humor*, or even a plea for assistance, or how a speeding heartbeat and an aching stomach might become an experience of *anxiety, excitement*, or *embarrassment.* In constructing ad hoc emotion concepts, the brain's internal model cannot rely upon statistical regularities from the physical or perceptual features of previous instances, but must anchor on the goal-based function those instances served. The brain also has access to the emotion words that were used in previous instances, and were used by parents and caregivers to label emotional events during development.

[Figure 2 near here]

A Predictive Processing Hypothesis for Emotional Development

We propose that a predictive processing account of brain function can be used to describe how infants learn to experience and perceive emotions. An infant brain does not have an internal model of its body in a dynamically-changing physical and social world; it must build one. At first, an infant's internal model does not predict efficiently, and must encode most sensory inputs as unanticipated prediction error (Atzil et al., 2018; Barrett, 2017a). The brain uses this prediction error to adapt its model, progressively refining the ad hoc concepts it constructs to guide action and give sensations meaning (Kirkham, Slemmer, & Johnson, 2002; Tenenbaum, Kemp, Griffiths, & Goodman, 2011). An infant brain begins to construct ad hoc emotion concepts through sufficient experience in which it has observed that certain events (variable in their features) serve particular goal-based functions in particular situations (e.g., to overcome an obstacle, one can cry, throw a toy, refuse to move, or withdraw). As proposed above, our hypothesis is that infants learn these functional similarities through statistical or reinforcement learning (Krogh, Vlach, & Johnson, 2012; Saffran, Aslin, & Newport, 1996; Siegelman & Frost, 2015) that is probabilistic and guided by language. Each time a caregiver labels the infant or someone else as ‘angry’, for example, the infant may learn to associate these physically, perceptually, and psychologically different instances with the same emotion category. This hypothesis directly parallels the ’blork’ example discussed earlier, in which infants learn to expect perceptually different objects that share the same label to also share the same nonobvious features (Graham et al., 2004; Welder & Graham, 2006). In predictive processing terms, infant brains may be continually modifying their internal models to associate emotion words with the sensory array (both internal and external) at the time those words are used.

To understand the exact role words play in the emotional developmental trajectory, there are several questions of interest. First, when do caregivers and other people in an infant’s social world begin using emotion words? Language shapes development for object concepts because adults actively and frequently name objects for infants. There is little evidence of how frequently adults deliberately or indirectly use emotion words to label emotional events when infants are present. This is something that likely varies substantially with culture, socioeconomic status, the granularity of the adults’ concepts, and even an infant’s gender (e.g., Cervantes & Callanan, 1998; Eisenberg, 1999). Second, which episodes are labeled for infants and young children? One possibility is that adults sample only the most stereotypic instances of emotion categories. These “curated” categories may be largely perceptually based, missing the variability of more mature emotion concepts, which might be learned later. Alternatively, it is possible that adults label highly variable events with emotion words, forcing infants to grapple with the variation up front, so that they are learning abstract, conceptual categories from the start. Third, it is conceivable (though not supported by the current evidence) that certain emotion categories may have instances that share perceptual features, and that these “typical” instances can be learned without words. In any case, it seems clear that emotion words are necessary for children to develop mature emotion concepts. As language input becomes more available and more useful, emotion words may serve as cues to integrate instances that share fewer perceptual features and to impose functional similarity, helping the child to revise her internal model to resemble that of adults in her culture.

This proposal contrasts with other approaches in how they understand the mechanisms and timelines for emotional development. Many scientists hypothesize that emotional behaviors are innate, biologically determined responses to stimuli (e.g., Frijda, 1986; Ratner, 1989) or mechanisms of social regulation (e.g., Campos & Barrett, 1984; Trevarthen, 2005). By most accounts, these inborn behaviors can be adapted or elaborated by social learning to achieve the emotional experiences of enculturated adults (e.g., Lambie, 2009; Ratner, 1989), though social learning may not be necessary for the emergence of emotional reactions such as facial movements (Campos & Barrett, 1984; Klinnert, Campos, Sorce, Emde, & Svejda, 1983). As we have proposed, infants do not come prewired with emotion concepts to guide experience or perception. Instead, infants' apparent perception of facial emotion in parents and caregivers is a result of statistical and/or reinforcement learning, as infants come to relate these cues to the consequences of caregivers' behavior. Further, as reviewed above, evidence suggests that infants do not perceive differentiated emotions (e.g., *anger, sadness, fear*) in adults' faces, but may instead discriminate based on the affective dimensions of valence and arousal.

A predictive processing account of emotional development also distinguishes itself from other approaches with regard to the role of language. While some accounts see language as epiphenomenal to emotion concept acquisition (e.g., Campos & Barrett, 1984; Frijda & Mesquita, 1998), we propose that language – in particular, emotion words – plays a causal role in emotional development. This is not to say, however, that emotion concepts and categories are reducible to words (Lambie & Marcel, 2002). On the contrary, we hypothesize emotional development is multicausal, emerging from interactions between an embodied, growing brain and the physical, social, and linguistic world (Smith & Gasser, 2005; Smith & Thelen, 2003). This complex dynamic system cannot be reduced to its constituents; theories of emotional development must include all aspects and levels of analysis. By accounting for the role of the body and brain, social interactions, language and culture in emotional development, we have proposed just such an account.

Evidence for a Predictive Processing Account of Concept Construction and Development

A growing body of research on language processing supports a predictive processing account of concept construction. This research uses electroencephalography (EEG) to measure event-related potentials (ERPs),[4] which indicate when prediction errors occur, i.e., when sensory input violates a brain's existing expectations. Later ERP components are thought to reflect semantic or conceptual prediction errors (specifically, the N400) and errors in the prediction of event segmentation or structure (specifically, the P600), whereas earlier ERP components are thought to reflect perceptual prediction errors (e.g., Kuperberg, 2016; Kuperberg & Jaeger, 2016). Studies have observed N400-like responses to semantic or sequential incongruity in infants. For example, semantic incongruity between early-acquired nouns and pictures of familiar objects (e.g., cat, ball, car, mouth) produces an N400 as young as nine months (Junge, Cutler, & Hagoort, 2012). Infants at this age also produce N400-like responses when conclusions are violated for simple sequences of actions performed by human actors (e.g., eating a spoonful of food), suggesting that they are able to predictively infer goals (Reid et al., 2009). N400 effects have also demonstrated the social and linguistic basis for early concept development: joint attention helps infants learn new words (Hirotani, Stets, Striano, & Friederici, 2009), and infant-directed speech enhances statistical learning in newborns (Bosseler, Teinonen, Tervaniemi, & Huotilainen, 2016).

Without predictions (i.e., ad hoc concepts), there can be no prediction error. As a consequence, it may be possible assess concept development using ERPs. The N400 emerges gradually over time as the brain develops (Carver et al., 2003; Webb, Long, & Nelson, 2005), and so may not be readily interpretable when testing infants in the first few months of life. Published ERP studies of emotion perception in infants (for a review, see Grossmann, 2015) often focus on the Nc, a component thought to reflect attentional bias or the perceptual salience of stimuli (for a review, see de Haan, 2007). These findings are consistent with the hypothesis that infants as old as seven months rely on physical differences rather than emotional meaning to distinguish between smiling and scowling faces (Caron, Caron, & Myers, 1985). Nonetheless, EEG measurement has the potential to provide novel insights into the emotionally developing brain. For example, the infant Nc may or may not be a developmental precursor of the N400 (de Haan, Johnson, & Halit, 2003). The Nc has been shown to be sensitive to global and local stimulus probabilities (e.g., Ackles & Cook, 1998), even in infants as young as one month (Karrer & Monti, 1995), and so may represent the rudiments of emerging prediction error signals.

More broadly, a predictive processing account of concept learning is supported by recent work on Bayesian and other probabilistic computational models of development (e.g., Gopnik & Bonawitz, 2015). In these models, concepts can be understood as stochastic functions that support probabilistic inference and are constructed via situation-specific induction (Goodman, Tenenbaum, & Gerstenberg, 2014). These models are also able to account for the role of social others in concept learning. Social context shapes the inferences learners make not only about the world, but also about knowledgeable others (Shafto, Goodman, & Frank, 2012). When children observe parents and caregivers, they are learning about them as well as from them (Bonawitz & Shafto, 2016). In this way, children are able to leverage caregivers' actions to make inferences about caregivers' goals and knowledge of the world, and can use these inferences to bolster learning and tune predictions. Linguistic input has been shown to similarly impact concept learning within these computational models (e.g., Frank, Goodman, & Tenenbaum, 2009; Piantadosi, Tenenbaum, & Goodman, 2012). Using this approach, future research may be able to specifically model the development and probabilistic construction of emotion concepts in infants and young children.

Our Proposal in Context

The insights afforded by a predictive processing account of concept learning lend themselves to a more nuanced understanding of how individuals and cultures construct emotion concepts, and how children's individual needs may be better accounted for in domains such as education and mental health. As a consequence, our proposal has many implications and considerations for the study of emotional development. We discuss several of these in the following section.

Implications for the Study of Emotional Development

In our framework, variation in the features of emotional events is considered meaningful and important. Variation is inherent in the acquisition of abstract, conceptual categories such as emotion categories: because instances of emotion categories lack statistical regularities in physical and perceptual features, infants must learn to abstract away from these details and foreground the emotion's goal-based function in a given situation. The corresponding emotion concepts are embodied, culture-specific, and – most importantly – dynamically changing over time as the child updates her internal model of the body in the world via social learning and language. In this way, our approach attempts to understand the richness of a child's emotional life on a moment-to-moment basis. The same possibility is not offered by other approaches that hypothesize a small set of inborn or early-to-develop universal emotions, in which each emotion is thought to have its own diagnostic facial expression, pattern of autonomic nervous system activity, and so on.

It follows from a variation-based account of emotional development that there are no "correct" or "incorrect" emotion concepts because there are no single sets of physical features on which to make this determination. There are no perceiver-independent criteria for establishing category membership and, because of this, there is no ground truth for determining if someone's experience or perception of emotion in accurate. However, emotion categories can be described by similarities in their situation-specific functional features. These similarities are established via collective intentionality and reinforced via language. As such, even if there is no correct or incorrect way for children to form emotion categories (or construct emotional instances), children (and adults) can vary in how closely their experiences and perceptions align with the expectations and patterns of their culture (De Leersnyder, Kim, & Mesquita, 2015; De Leersnyder, Mesquita, Kim, Eom, & Choi, 2014). In a cultural context that values individual achievement, for example, a child may learn to construct the experience of *pride* when being singled out for an award at school; in a cultural context that values collective harmony, a child in the same situation may learn to construct the experience of *respectful deference* or even *embarrassment*. There is no right or wrong way to feel; what matters is whether the child's internal model is constructing emotions similarly to those around her.

Like other frameworks for emotional development (e.g., Campos & Barrett, 1984; Klinnert et al., 1983), our approach situates concept learning within social relationships, particularly the caregiver-infant bond. However, our approach contributes a unique perspective on the mechanisms underlying this bond and, critically, how they shape development. The core task of the brain, we hypothesize, is the maintenance of efficient physiological regulation. Social others also serve this purpose (Atzil & Barrett, 2017), especially in the context of an infant and her parents and caregivers (e.g., Winberg, 2005). Caregivers regulate infants' bodily systems through food, clothing, touch, and more. This regulation is a rewarding process for the infant (Keramati & Gutkin, 2014) that may motivate her to learn emotion concepts. Whereas joint attention is useful for highlighting physical and perceptual features of the environment that are culturally-relevant, something more is needed for infants to acquire abstract concepts, such as emotion, that lack statistical regularity in these features. We propose that social bonding fills this need by providing the medium in which abstract concepts can become meaningful (Atzil et al., 2018). An infant brain will likely prioritize sensory inputs associated with her caregiver, and will tune its internal model accordingly; it will learn to construct emotion concepts as a means of predicting the physiological outcomes of caregiver interactions. For example, learning that a heavy sigh or a widened eyes from a caregiver, associated with the word 'angry' are followed by decreased touch and attention will encourage the infant brain to develop situations-specific ad hoc concepts for *anger*. In other words, social bonding is what makes emotion concept learning not only useful for the infant, but imperative for predictive (and therefore metabolic) efficiency.

Similarly, our approach underscores the fundamental relationship between motor learning and emotional development. By building an internal model that can construct ad hoc concepts, the infant brain begins to yoke motor activity to sensory experience during emotional events.

Predictions guide action by preparing the body to make a series of movements, while accounting for the energy these movements will require. To estimate which movements are best suited to the context, the brain must also make predictions about the causes behind the current sensory array. Predictions for sensation are a consequence of predictions for action. In this regard, our proposal is consistent with work on human vitality, which relates emotions to prospective (rather than reactive) control of motor and autonomic activity, as guided by the body's projected metabolic costs (Trevarthen, 1999, 2005). Ad hoc emotion concepts, as predictions, serve to categorize sensation and construct experience. Infants learn to make these predictions through sensorimotor interactions with the world, during which they acquire embodied and enactive concepts (e.g., Bruner, 1964; Piaget, 1936/1952; Smith & Gasser, 2005).

Finally, our framework helps to better explain why existing emotional intelligence training programs work as they do, thereby improving child well-being. Social and emotional learning initiatives have shown that children are better equipped for school when they have more elaborated emotional vocabularies. For example, the RULER Feeling Words Curriculum (Maurer & Brackett, 2004) is designed to help children gain a deeper understanding of emotion words, with lessons that focus on the situated and multi-faceted nature of emotional experience. Through these lessons, we hypothesize, children learn new emotion concepts or expand the situation-specific variation in the ones they have. Emotional intelligence training programs, then, add flexibility to the brain's internal model, allow for more tailored predictions. Further, as emotion concepts are tools for physiological and behavioral co-regulation, these updates to the internal model should result in improvements in children's experienced affect as well as the social environment. Indeed they do: children in classrooms implementing RULER perform better in school and have better social relationships (Brackett, Rivers, Reyes, & Salovey, 2012); in turn, these classrooms exhibit better connectedness, organization, and emotional support (Hagelskamp, Brackett, Rivers, & Salovey, 2013; Rivers, Brackett, Reyes, Elbertson, & Salovey, 2013). These findings are echoed by studies showing that greater emotional fit with one's culture predicts both relational satisfaction (De Leersnyder et al., 2014), psychological well-being (De Leersnyder et al., 2015), and even physical health (Consedine, Chentsova-Dutton, & Krivoshekova, 2014).

Caveats and Considerations

In this paper, we have proposed that emotion categories are abstract, conceptual categories that are forged in social reality, where a concept helps to constitute a category in a given situation (see also Barrett, 2012). Different autonomic nervous system changes, facial movements, vocalizations, and so on have no emotional meaning in and of themselves. They are transformed into emotions by being categorized with concepts that exist by virtue of collective intentionality. This does not mean that the experience and perception of emotion is not grounded in biology: at the core of our account is the hypothesis that emotional events, like all mental events, fundamentally occur within a brain that anticipates the body's energy needs in relation to the current context. Nor does our proposal imply that an emotion is whatever an individual chooses to categorize or label as such. Instead, our approach is consistent with the view that concept development occurs within a social context, necessarily constraining transmission along cultural lines (Gelman & Roberts, 2017). In this way, our proposal accounts for documented cultural variation in emotional meaning-making. For example, the Trobriand Islanders impose emotional meaning on a stony, wide-eyed gasping face, and a racing heart, thereby creating an instance of *anger* that achieves a particular goal, such as warning away an enemy (Crivelli, Russell, Jarillo, & Fernández-Dols, 2016). Other groups of people impose a different emotional meaning on the same occurrence, creating an instance of *fear* that achieves a different goal, such as warning others of a threat (Shariff & Tracy, 2011). Still another group of people might impose no emotional meaning on this occurrence (e.g., a person is taken to be merely looking), or if they do, they understand emotions as externally-oriented actions rather than as intentions or feelings (e.g., a person is not 'angry', but 'yelling'; Vallacher & Wegner, 1987).

Further, we have proposed that emotion words serve as invitations for children to learn emotion concepts, and that this developmental process provides them with the ability to construct emotional experiences and perceptions. Our hypothesis is based on an analogy to how infants use words to construct object categories and to identify relevant attributes or properties of objects. Existing studies of child-directed emotion language (e.g., Beeghly et al., 1986; Dunn et al., 1987) do not fully test our hypothesis because they have not continuously sampled caregiver-infant interactions, nor have they measured emotion words that infants may hear used around (but not toward) them. Furthermore, that words may plan an active part in guiding emotional development does not necessarily imply that development is solely linguistic or dependent upon emotion words. Evidence suggests instead that infants are active learners who, rather than passively awaiting the imprint of the input language, develop nonlinguistic concepts (e.g., Bowerman & Choi, 2001; Trevarthen & Delafield-Butt, 2017) through a variety of domain-general learning processes (e.g., Aslin, 2017; Atzil et al., 2018; Barrett, 2017a; Smith, 1999). As children begin to talk and verbally interact with parents, caregivers, and others in their social environment, their conceptual repertoire grows and differentiates (Nook, Sasse, Lambert, McLaughlin, & Somerville, 2017). Across the lifespan, concepts are acquired and updated based both on embodied experience of the world, as well as statistical regularities in the linguistic environment (Vigliocco et al., 2009).

Future Directions

A predictive processing account of emotional development has the potential to stimulate new lines of research. In addition to the hypotheses we have listed throughout our discussion, many interesting empirical questions remain open (Table 1). Addressing these hypotheses and questions requires an integrated, multidisciplinary approach. Emotion construction and development are more variable, multi-dimensional, and context-dependent phenomena than often supposed. If our approach bears empirical fruit, however, then it will resolve a long-standing debate about the nature of emotion. It provides a developmental account of emotion that is biologically based without relying on nativist assumptions, and dissolves the artificial boundaries between nature and nurture. It provides an evolutionary account of emotion, where the evolutionary legacy to the newborn may not be a set of modular emotion circuits that are hardwired into the subcortical features of the mammalian brain, with corresponding facial expressions or autonomic fingerprints, but instead, may be a set of mechanisms that allow a child's brain to wire itself to the social realities that she grows up in, thereby extending her biological capacities with cultural know-how. Such discoveries would have important implications for enhancing education and children's well-being.

[Table 1 near here]

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Declaration of Interest Statement

The authors declare no conflict of interest.

[1] It has been long assumed that emotion perception studies provide an indirect way of testing hypotheses about emotional expressions because the two must have co-evolved as an integrated signaling system (Ekman, Friesen, & Ellsworth, 1972; Jack, Sun, Delis, Garrod, & Schyns, 2016; Shariff & Tracy, 2011).

[2] It is notable that the majority of these studies have focused on studying the most stereotypic instances of emotion, and include few instances from each category on the (typological) assumption that they are interchangeable. Despite this, variation continues to be observed. As such, it is reasonable to assume that published findings underestimate the amount of within-category variation in the physical features of emotion.

[3] Active inference has been observed in exteroceptive sensory systems (for a brief review, see Chanes & Barrett, 2016) as well as the skeletomotor system (e.g., Shadmehr, Smith, & Krakauer, 2010), and may also apply to the visceromotor and interoceptive system (Barrett & Simmons, 2015). Many psychological phenomena are being understood as the result of active inference, including perception (e.g., O'Callaghan, Kveraga, Shine, Adams, & Bar, 2017), remembering (e.g., Hindy, Ng, & Turk-Browne, 2016), language (e.g., Lupyan & Clark, 2015), attention (e.g., Feldman & Friston, 2010), emotion (e.g., Barrett, 2017a, 2017b; Seth, 2013), mood (e.g., Barrett & Simmons, 2015; J. E. Clark, Watson, & Friston, 2018), social cognition (e.g., Tamir & Thornton, 2018), and even consciousness (e.g., Chanes & Barrett, 2016; Seth, Suzuki, & Critchley, 2012).

[4] Magnetoencephalography (MEG) has similarly excellent temporal resolution and can also be used to measure event-related brain activity (in this case, event-related fields or ERFs). We focus on the ERP literature here because it is more extensive and has specifically been used to test a predictive account of semantic processing.

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Table 1. Questions Generated by a Predictive Processing Account of Emotional Development

The Role of Parents and Caregivers

1) Do parents and caregivers consistently create emotional instances for infants and young children by labeling according to when they (the parents) perceive emotion, and if so, when does this begin?

2) Do parents and caregivers label only the most stereotypic instances of an emotion category at first, or do they label the highly variable instances that exist in everyday life?

Emotions vs. Other Types of Categories

3) How well can young learners use emotion labels to acquire emotion categories, whose instances are temporally dynamic and require event segmentation when compared with objects?

4) Do infants learn abstract emotion categories much like how they learn superordinate categories?

Timelines for Development

5) Do infants perceive emotional events as multimodal to begin with? If so, do emotion words help infants detect or discriminate the modal features of an emotional event, such as an expressive facial movement or vocalization? Or do words help bind multimodal features together?

6) When do inferences about goals and intentions become part of emotional events? Do words facilitate this?

Cultural Relativity

7) Are emotion concepts that are not labeled with a single, commonly-accepted word transmitted from generation to generation with as high of fidelity as labeled emotion concepts?

8) Are goals and intentions important for emotion concepts around the world, or is there cultural variation in this regard (given that people who live in non-western cultural contexts may be more likely to assume that other peoples' minds are not accessible to them, and therefore may be less likely to engage in mental inference, a phenomenon called opacity of mind; Danziger, 2006; Robbins & Rumsey, 2008)?

Building the Internal Model

9) Is word-guided emotion learning driven by statistical learning or reinforcement learning?

10) Do emotion concepts allow infants and young children to perceive emotions in others and experience emotion themselves?

New Methods of Investigation

11) Can ERP studies be used to investigate the role of words in pre-verbal emotion concept development, for example by comparing infant responses to variable, multimodal stimuli that are either labeled with the same emotion word or not?

12) Can computational models successfully predict the development and probabilistic construction of emotion concepts in infants and young children, and what is the relative role that language, social bonding, and other factors play?

Box 1. *The Current Approach vs. Existing Approaches*

The present approach to emotional development follows a number of constructionist theories. In line with social constructionism, our proposal suggests that emotion categories are a product of social reality and are culturally relative; similarly, emotion concepts develop through contextualized social interactions in which language plays a significant part (Harré, 1986; Lutz, 1983; Ratner, 1989). In this way, our proposal is consistent with perspectives that highlight the inherent intersubjectivity of emotional development (Stern, 1985; Trevarthen, 1984). However, our proposal extends beyond these perspectives to emphasize the role of the body and its anticipated energy needs. Social constructionism holds that emotion concepts are inherently about the relationship between social interactants. In comparison, a predictive processing account anchors the construction of emotion concepts (like all concepts) in the service of efficient physiological regulation. Humans interactively establish and reinforce emotion categories to co-regulate each other (e.g., Barrett, 2017a; Campos et al., 1989; Klinnert et al., 1983), but this is always in support of keeping bodily systems in balance.

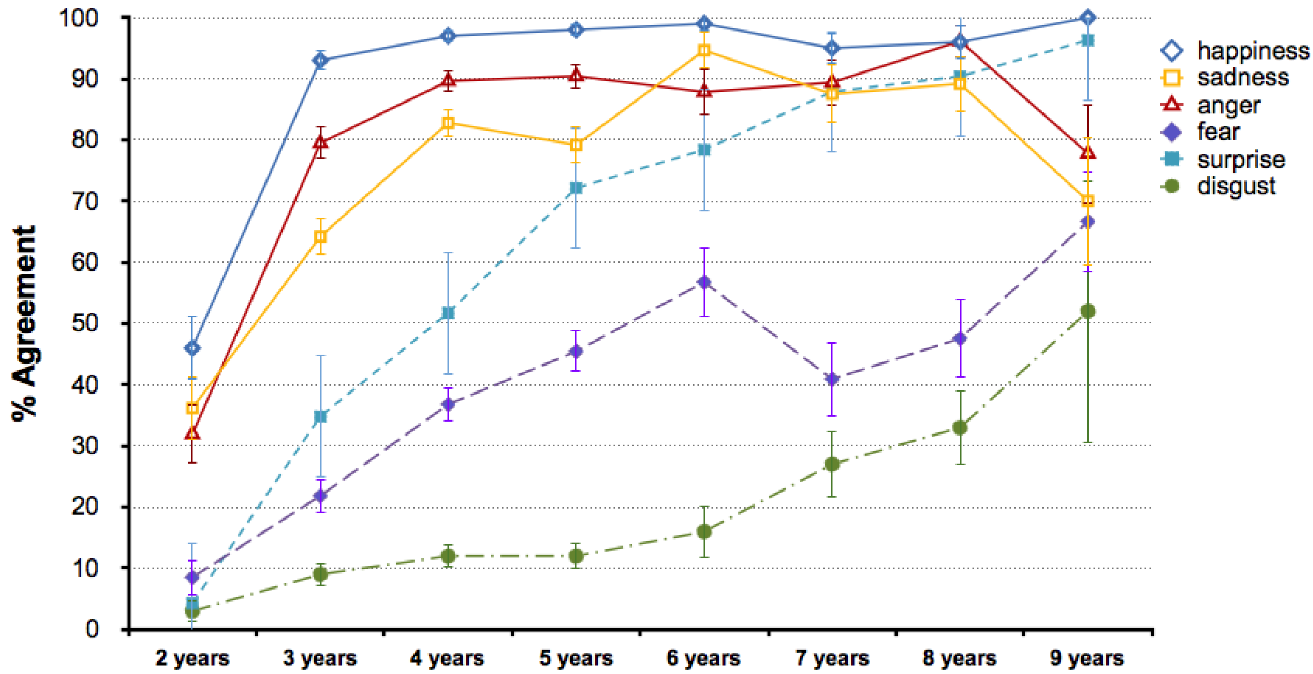

Figure 1. *Developmental trajectories for emotion concept development.* Taken from Barrett et al. (forthcoming). Adapted from Widen (2016) with permission. Data from 11 studies were aggregated (for details, see Widen, 2016). In these studies, children are asked to freely label faces (e.g., Widen & Russell, 2003) or choose a label for a face from a small set of options (e.g., Pollak, Messner, Kistler, & Cohn, 2009). From an early age, children used the expected emotion labels (with standard errors) for the stereotypical smiling faces ("happiness"), the scowling faces ("anger"), and the frowning faces ("sadness") but the expected emotion labels for the other faces gradually increased with age. Total N = 1065. The N for each age group was: two years (N=94), three years (N=229), four years (N=299), five years (N=209), six years (N=74), seven years (N=66), eight years (N=61), and nine years (n=33).

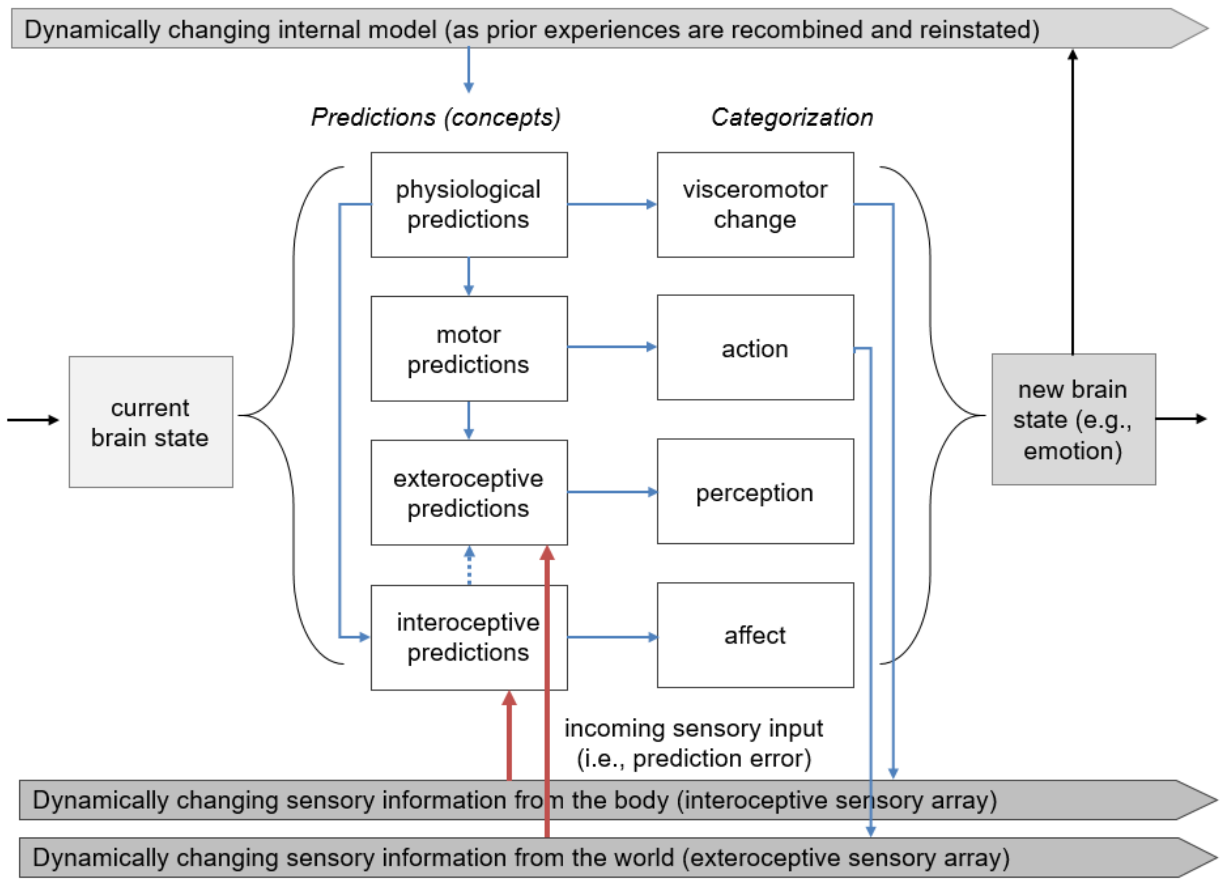

Figure 2. *Schematic depiction of a hypothesis for dynamic emotion construction with ad hoc emotion concepts as prediction signals*. Adapted from Hoemann and Barrett (2018). Blue lines indicate top-down signal; red lines indicate bottom-up signal. Based on the current brain state, previous experience is used to generate a cascade of predictions focused on meeting the body's expected needs for action. As depicted, unanticipated changes in sensory input (i.e., prediction error) may result in further tuning of the predictions. When predictions are confirmed, the current sensory array has been categorized and the brain transitions from one location in state space to another (i.e., a new mental event is occurring). Visceromotor changes and actions, in turn, impact sensory inputs from the body and world, respectively. Current experience also updates the internal model, becoming part of the previous experience that will be brought to bear in future predictions.