The Development of Emotion Understanding in Infancy

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Abstract

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An ongoing debate in affective science concerns whether emotion understanding is (a) an early emerging or innate ability, based in our shared evolutionary history, or (b) an ability that develops slowly over time, shaped by language and social experience. Although many studies suggest that preverbal infants differentiate positive and negative facial expressions (e.g., happy vs. anger), few studies have tested how infants "understand" discrete emotions (e.g., anger vs. disgust). This dissertation presents three papers that explore how infants interpret and categorize discrete emotional expressions across the first two years of life. Paper 1 (*Chapter 2*) tested whether 14- and 18-month-olds ($N = 336$) can match specific negative emotions (e.g., disgust) to different negative events (e.g., eating food). Paper 2 (*Chapter 3*) tested whether 14- and 18-month-olds ($N = 272$) perceive different facial expressions (e.g., sadness and disgust) as belonging to a superordinate category of negative valence, and whether verbal labels facilitate the formation of this category. Paper 3 (*Chapter 4*) explored potential changes in 10- and 14-month-olds' ($N = 240$) ability to match specific negative emotions to events. Taken together, these findings suggest that preverbal infants' understanding of discrete emotions is emerging

across the first two years of life. In particular, infants may be able to learn about some aspects of discrete emotional emotions (e.g., eliciting events) around 14- to 18-months of age, before the development of emotion language. However, language appears to play a role in constructing infants' emotion categories. These papers advocate for a revision of existing emotion theories in order to account for the emerging abilities of preverbal infants.

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In loving memory of Robert “Kito” Bizieff, who ignited my interest in the human mind. Thank you for being a part of my story.

Chapter 1. INTRODUCTION

Over the past century, there has been much disagreement about the nature of human emotion. One ongoing debate centers on whether (a) certain discrete, "basic" emotions have evolutionary-based signals (i.e., facial expressions) that are easily and universally identified (Ekman, 1994; Izard, 1994), or whether (b) emotion experience, expression, and perception are highly variable processes, influenced by language (Barrett, 2017; Russell, 1994). Empirical work exploring this debate has primarily focused on adults or children who are able to verbally communicate. Largely missing are studies with preverbal infants (younger than 24-months). Preverbal infants, who have comparatively little experience with language and others' emotions, could potentially elucidate whether emotion understanding is (a) an early emerging or innate ability, based in our shared evolutionary history, or (b) an ability that develops slowly over time, shaped by language and social experience. However, there is currently a lack of collaboration between developmental and affective science. This has led to affective scientists citing select infancy studies as evidence for their theories (Barrett, 2017; Lindquist & Gendron, 2013), even though most infancy studies were never designed to test or inform these issues.

This dissertation provides the first explicit empirical tests of these competing theories. *Chapter 1* reviews the existent literature on emotion understanding development in infancy. *Chapters 2-4* describe three empirical papers that test how 10-, 14-, and 18-month-olds categorize and interpret discrete emotional expressions. *Chapter 5* outlines methodological recommendations, a new hypothesis for infants' emotion understanding development, and directions for future research. Overall, the goal of this dissertation is to advocate for increased collaboration between developmental and affective science, in order to answer fundamental questions about the nature of human emotion.

1.1 Emotion Theories and the Development of Emotion Understanding

Emotion theories are often categorized as either "classical" or "constructionist" (for a list of specific theories, see Barrett, 2016). In short, classical theories argue that certain "basic" emotions—typically happiness, sadness, anger, fear, surprise, and disgust—have corresponding facial expressions that are evolutionarily-based, universal, and easily recognized in others (Ekman, 1994; Izard, 1994). In contrast, constructionist theories reject the idea of universal, basic emotion signals (Russell, 1994). Instead, these theories argue that emotions are experienced and expressed in highly variable ways. One particular constructionist theory, the "theory of constructed emotion" (Barrett, 2017), further argues that emotion words (e.g., "happy") impose a categorical structure on these variable emotional expressions. In this theory, language is fundamental to emotion perception and understanding. In-depth discussions and detailed descriptions of these theories can be found in many excellent books (e.g., Barrett, 2017; Ekman, 2017).

Each theory has made different predictions about the nature and development of infants' emotion concepts, or "conceptual emotion categories." In general, a "category" is a collection of objects, actions, or events that are considered to be equivalent in some way. Constructionist theories have argued that preverbal infants have *perceptual* emotion categories, based on salient facial features (Barrett, Lindquist, & Gendron, 2007). For example, prototypical happy expressions have upturned smiles, whereas prototypical fearful expressions have wide eyes (Ekman & Friesen, 1975). In this way, young infants need not attribute any affective meaning to these stimulus configurations. If preverbal infants do have *conceptual* emotion categories, constructionist theories argue that these are based on broad dimensions of valence (positive vs. negative) and arousal (high vs. low) (Barrett, 2017; Russell, 1980). These broad, valence- and

arousal-based concepts are thought to gradually narrow into discrete emotion concepts over the first decade of life (Widen, 2013). According to the theory of constructed emotion, this broad-to-narrow progression occurs alongside the acquisition of emotion labels (e.g., "happy"). In particular, it is argued that emotions occur with such unpredictability that learning of discrete emotion concepts may be difficult, or impossible, without exposure to emotion language (Barrett, 2017; Shablack & Lindquist, 2019).

Classical views have not always made firm predictions about infants' ability to understand emotional expressions. However, given the evolutionary importance of facial expressions to these theories, it follows that discrete emotion concepts for "basic emotions" are innately specified, rather than predominantly learned or language-dependent (Ekman, 2017). Although not all classical theorists have explicitly endorsed the existence of an innate or easily acquired conceptual system for emotions, others have made this assertion (Izard, 1994; C. A. Nelson, 1987). In a similar vein, some have argued that infants initially have *perceptual* emotion categories that transform into *conceptual* categories sometime in the first year of life, *before* emotion labels are acquired (Walker-Andrews, 1997). In a classical view, discrete emotion concepts are based on the communicative intent of emotional expressions (e.g., happy expressions indicate safety; Shariff & Tracy, 2011).

In the following review, I (a) summarize what is currently known about infants' understanding of emotional expressions, and (b) discuss the findings in relation to classical versus constructionist views of emotion. Although facial expressions of emotions are the primary focus of this review—for they have garnered the most empirical attention—other expressive behaviors (i.e., voice, body) are also considered where possible. Different components of infants' emotion understanding are also discussed, from more "basic" or "foundational" skills

(*discrimination*, *categorization, intermodal matching*) to more "advanced" abilities (*event-emotion matching, social referencing*; for similar developmental sequences, Walker-Andrews, 1997; Walle & Campos, 2012). This review also differentiates between research comparing (a) between-valence expressions (e.g., happy vs. anger), and (b) within-valence expressions (e.g., anger vs. fear). The vast majority of studies have tested emotional expressions *across the dimension of valence*. Consequently, it is impossible to determine whether infants are responding to these expressions based on valence alone (positive vs. negative) or discrete emotions (e.g., happy vs. anger). To determine whether infants have discrete emotion concepts, researchers need to compare expressions *within one dimension of valence and arousal* (e.g., high arousal, negative emotions such as anger and fear). If compelling evidence were obtained that preverbal infants have discrete emotion concepts, this would call into question the claims put forward by constructionist theories (Widen, 2013), particularly those that anchor these concepts to language learning (Barrett, 2017).

1.2 Emotion Discrimination

Emotion discrimination – perceiving the difference between two expressions (e.g., happiness vs. fear) portrayed by the same person (Walker-Andrews, 1997) – is the most fundamental ability for emotion understanding. Discrimination studies generally use static photographs of posed facial expressions from validated databases (e.g., Tottenham et al., 2009), although a handful of studies have tested vocal expressions, body expressions, or dynamic, multimodal (facial and vocal) expressions. In studies of facial expressions, female faces are typically used because infants have a visual preference for these faces relative to male faces (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). While most studies have used looking-time

paradigms, in the last fifteen years, researchers have also measured event-related potentials (ERP). This section describes these two methods separately.

1.2.1 *Looking-Time Paradigms*

Infant emotion discrimination has traditionally been measured with looking-time paradigms (for detailed discussion, see Oakes, 2010). In most *paired-preference paradigms*, infants are shown two static facial expressions side-by-side. If infants look longer at one expression compared to the other, it is assumed that they (a) have a visual preference and (b) can discriminate the expressions. These looking time differences are thought to reflect either a familiarity preference (e.g., in the case of happy expressions; Farroni, Menon, Rigato, & Johnson, 2007) or a novelty preference (e.g., in the case of fearful expressions; C. A. Nelson & Dolgin, 1985). However, if infants look equally long at both expressions, it is impossible to determine whether they (a) are unable to discriminate the expressions or (b) simply do not have an expression preference. *Familiarization* and *habituation paradigms* provide a more conclusive test of emotion discrimination. In these paradigms, infants are repeatedly shown one expression (e.g., happiness). After a fixed number of trials (familiarization) or after infants' looking time decreases to a certain criterion (habituation), infants are sequentially shown a novel expression (e.g., sadness) and a familiar expression (e.g., happiness). Infants provide evidence of discrimination if they look longer at the novel expression. Although these studies generally indicate that infants discriminate between various emotional expressions, findings depend on the (a) stimuli (static vs. dynamic), (b) paradigm (paired-preference vs. habituation/familiarization), and (c) expression contrast (e.g., happy-anger vs. happy-fear).

1.2.1.1 Between-valence

There is disagreement regarding when emotion discrimination first emerges (see (Grossmann, 2010; Quinn et al., 2011, for reviews). Although it has been reported that newborns discriminate happy from sad and fearful facial expressions (Farroni et al., 2007; Field et al., 1983; Field, Woodson, Greenberg, & Cohen, 1982), these findings are controversial. In particular, limitations in infants' visual systems (e.g., contrast sensitivity, face scanning, visual acuity) should make facial expression discrimination difficult prior to about 4-months of age (C. A. Nelson, 1987). In fact, when tested with static images, 3- and 4-month-olds do not reliably discriminate positive from negative facial expressions (Barrera & Maurer, 1981; Young-Browne, Rosenfeld, & Horowitz, 1977). On the other hand, infants at this age may discriminate between dynamic, multimodal (facial and vocal) expressions. For instance, 4-month-olds discriminate multimodal happy expressions from angry and fearful expressions, but findings are less consistent for happy-sad comparisons (Flom & Bahrick, 2007; Flom, Bahrick, & Pick, 2018; Kahana-Kalman & Walker-Andrews, 2001; Montague & Walker-Andrews, 2001). In these studies, however, it is unclear whether infants are simply responding to movement differences between the stimuli (Grossmann & Jessen, 2017).

Due to ceiling effects in infants' visual attention to dynamic facial expressions (Heck, Panneton, & Mills-Smith, 2016), emotion discrimination studies have typically used static stimuli. Further, given the limitations in younger infants' visual capacities, most research has focused on infants 5 months of age and older. With few exceptions (Grossmann & Johnson, 2007; LaBarbera, Izard, Vietze, & Parisi, 1976), 5- to 14-month-olds do *not* appear to have a visual preference for happy over angry expressions (Krol, Monakhov, Lai, Ebstein, & Grossmann, 2015; LoBue & DeLoache, 2010; Schwartz, Izard, & Ansul, 1985; Soken & Pick,

1992, 1999; Wilcox & Clayton, 1968). On the other hand, by 7-months, infants have a preference for fearful over happy facial expressions (de Haan, Belsky, Reid, Volein, & Johnson, 2004; Geangu et al., 2016; Krol, Monakhov, et al., 2015; LoBue & DeLoache, 2010; C. A. Nelson & Dolgin, 1985; Peltola, Leppänen, Mäki, & Hietanen, 2009; Safar & Moulson, 2017).

As noted earlier, a lack of preference does not necessarily indicate an inability to discriminate two facial expressions. *Familiarization/habituation* studies have indicated that, by 5-months, infants discriminate positive (i.e., happy) from negative facial expressions (e.g., sad, anger, fear), albeit only after habituation to happiness (Bornstein & Arterberry, 2003; Kestenbaum & Nelson, 1990; Nelson, Morse, & Leavitt, 1979; Nelson et al., 2006; although see Flom & Bahrick, 2007; Leppänen, Richmond, Vogel-Farley, Moulson, & Nelson, 2009). These habituation asymmetries are common, especially when infants are familiarized/habituated to fearful expressions (C. A. Nelson et al., 1979; Parker & Nelson, 2005). It is thought that the novelty/negativity of fearful expressions sustains infants' attention during the habituation events. Consequently, infants remain highly attentive to these expressions at test.

A handful of studies have also examined whether infants can discriminate between emotional expressions expressed in the voice and the body. In general, by 5-months of age, infants provide evidence of discriminating happy vocal expressions from sad and angry vocal expressions (Erlich, Lipp, & Slaughter, 2013; Flom & Bahrick, 2007; Mastropieri & Turkewitz, 1999; Walker-Andrews & Grolnick, 1983; Walker-Andrews & Lennon, 1991). One study has also found that 3.5-month-olds can discriminate between happy and angry body expressions (Heck, Chroust, White, Jubran, & Bhatt, 2018).

1.2.1.2 Within-valence

Only a few looking-time studies have explored whether infants discriminate between within-valence expressions. In an early study, 5-month-olds discriminated sadness and fear from anger, but not when anger was the familiarized emotion (Schwartz et al., 1985). This is consistent with findings that 7-month-olds (a) have a preference for angry over sad expressions (Soken & Pick, 1999), and (b) can discriminate between sadness and anger on unimodal facial expressions (Flom & Bahrick, 2007). Finally, although 5-month-olds discriminate between sadness and fear (Schwartz et al., 1985) older infants (13- to 24- month-olds) only discriminate when sadness is the familiarized expression (C. A. Nelson et al., 2006). In terms of vocal expressions, infants as young as 5-months, and perhaps newborns (Mastropieri & Turkewitz, 1999), have been found to discriminate between sad and angry vocal expressions (Flom & Bahrick, 2007; Walker-Andrews & Lennon, 1991). Although not reflective of "basic" emotion discrimination, it has also been reported that 6- and 8-month-olds discriminate between "triumph" and "relief" vocal expressions (Soderstrom, Reimchen, Sauter, & Morgan, 2017), suggesting that infants can differentiate within-valence, positive vocalizations.

1.2.2 *Event-Related Potential (ERP) Paradigms*

Researchers initially turned to ERP paradigms to examine why infants have visual preferences for some facial expressions (e.g., fear) over others. In these paradigms, infants observe multiple brief (< 1000ms) presentations of static facial expressions. ERPs are averaged from a continuous recording of electrical signals at the scalp, time-locked to the presentation of each expression. Infant studies have primarily focused on three ERP components: the N290, P400, and Nc (negative central). The N290 and P400 are thought to be "precursors" to the face-sensitive adult N170 (Rigato, Farroni, & Johnson, 2010), whereas the Nc is thought to relate to

increased allocation of attention (de Haan, Johnson, & Halit, 2003). While most studies examine 5- or 7-month-olds, a handful have tested older infants (Grossmann, Striano, & Friederici, 2007; Martinos, Matheson, & de Haan, 2012; Parker & Nelson, 2005; van den Boomen, Munsters, & Kemner, 2019; Xie, McCormick, Westerlund, Bowman, & Nelson, 2019).

1.2.2.1 Between-valence

Although there are many inconsistencies in the ERP literature (for a summary table, see (van den Boomen et al., 2019), the most reliable differences between positive and negative facial expressions have been found in the Nc. Multiple studies report that 7-month-olds have larger Nc amplitudes to fearful than happy expressions (de Haan et al., 2004; Grossmann et al., 2011; Jessen & Grossmann, 2014, 2015, 2017; Leppänen, Moulson, Vogel-Farley, & Nelson, 2007; Martinos et al., 2012; C. A. Nelson & de Haan, 1996; Peltola et al., 2009; Rajhans, Jessen, Missana, & Grossmann, 2016; Taylor-Colls & Pasco Fearon, 2015). These results suggest that infants allocate more attention to fearful expressions. In comparison, most studies fail to find differences in P400 and N290 responses to positive versus negative facial expressions at any age (Jessen & Grossmann, 2014, 2017; Leppänen et al., 2007; C. A. Nelson & de Haan, 1996; Parker & Nelson, 2005; Rigato et al., 2010; Vanderwert et al., 2015; Xie et al., 2019).

Recently, studies have also tested infants' discrimination of emotions presented in the voice and the body. With respect to the voice, 8-month-olds neurally differentiate between laughing and crying vocalizations, with larger N100/N200 responses to crying vocalizations and larger P200/P300 responses to laughing vocalizations (Crespo-Llado, Vanderwert, & Geangu, 2018; Missana, Altvater-Mackensen, & Grossmann, 2017). In addition, 7-month-olds show greater Nc responses to words spoken in an angry tone of voice compared to a happy tone of voice (Grossmann et al., 2013; Grossmann, Striano, & Friederici, 2005; for related findings using

NIRS, see Grossmann, Oberecker, Koch, & Friederici, 2010). Newborns also show a stronger EEG mismatch response (MMR) to angry and fearful vocal expressions compared to happy vocal expressions (Cheng, Lee, Chen, Wang, & Decety, 2012). The MMR represents automatic auditory discrimination (Näätänen, Paavilainen, Rinne, & Alho, 2007), suggesting that infants may have some innate capacity to differentiate between positive and negative emotional vocalizations.

With respect to the body, 8-month-olds have been found to have larger N290 responses and greater right frontal cortical activity to static fearful body expressions, compared to happy body expressions (Missana & Grossmann, 2015; Missana, Rajhans, Atkinson, & Grossmann, 2014). Right frontal cortical activity is associated with the motivation to withdraw (Buss et al., 2003; Davidson & Fox, 1982), suggesting that infants have associated the fearful body expression with behavioral avoidance and threat. In addition, 8-month-olds, but not 4-month-olds, show greater Pc (positive component) responses and greater left frontal cortical activity for dynamic happy body expressions, compared to fearful body expressions (Missana, Atkinson, & Grossmann, 2015; Missana & Grossmann, 2015). The Pc component is thought to reflect recognition memory (Grossmann, Striano, & Friederici, 2006; C. A. Nelson, Thomas, de Haan, & Wewerka, 1998), while left frontal cortical activity is associated with motivation to approach (Davidson & Fox, 1982; Fox & Davidson, 1988). This suggests that infants (a) had a familiarity preference for the happy body expression, and (b) associated happy body expressions with approach and safety. Greater Nc responses to fearful body expressions, compared to happy body expressions, have also been found, but only when the body expressions are static (Krol, Rajhans, Missana, & Grossmann, 2015; Missana et al., 2015, 2014). Infants who show greater Nc responses to fearful body expressions (i.e., a fear bias) tend to have a more fearful temperament

and mothers who express a high degree of empathetic concern (Rajhans, Missana, Krol, & Grossmann, 2015).

1.2.2.2 Within-valence

Most studies have also failed to find differences between anger, fear, and sad facial expressions for the Nc, N290, and P400 at any age (Hoehl & Striano, 2008; C. A. Nelson & de Haan, 1996; Parker & Nelson, 2005; Vanderwert et al., 2015; Yrttiaho, Forssman, Kaatiala, & Leppänen, 2014). However, in some studies, infants 7-months and older show greater Nc and N290 amplitudes to anger than fearful and sad facial expressions (Hoehl & Striano, 2008; Kobiella, Grossmann, Reid, & Striano, 2008; Parker & Nelson, 2005; but see, Xie et al., 2019). Findings are more variable for the P400. In some studies, 5- to 12-month-olds show greater P400 responses to anger facial expressions than fear (Hoehl & Striano, 2008; Xie et al., 2019), but greater P400 responses to fearful than anger and sad facial expressions have also been reported in 7- to 24-month-olds (Kobiella et al., 2008; Parker & Nelson, 2005).

1.2.3 *The "Fear Bias"*

One of the most consistent findings in both looking-time and ERP paradigms is heightened attention to fearful facial expressions compared to happy facial expressions (for a review, see Leppänen & Nelson, 2012). Infant researchers typically explain this "fear bias" in terms of the threat signaling value of fearful facial expressions (Jessen & Grossmann, 2014), which would be particularly adaptive for self-locomoting infants (Campos et al., 2000). Thus, the emergence of crawling is often used to explain why 7-month-olds, but not younger infants, attend more to fearful than happy facial expressions (Farroni et al., 2007; Grossmann & Jessen, 2017; Jessen & Grossmann, 2016; Leppänen, Cataldo, Bosquet Enlow, & Nelson, 2018; Martinos et al., 2012; Peltola, Hietanen, Forssman, & Leppänen, 2013; Peltola et al., 2009; but

see, Bayet et al., 2017; Heck, Hock, White, Jubran, & Bhatt, 2016, 2017). However, this is a "classical" explanation. In line with a constructivist view, there may be valence-based or perceptual explanations for these findings.

One possibility is that heightened attention to fearful expressions reflects a general negativity/threat bias (Vaish, Grossmann, & Woodward, 2008). This seems unlikely, however, given that 5- to 14-month-old infants do not have a visual preference for angry over happy facial expressions. Furthermore, even though 7-month-olds show larger Nc amplitudes in response to fearful than happy facial expressions, Nc differences are not found when anger is compared to happiness (Grossmann et al., 2007; Parker & Nelson, 2005). Thus, there may be something especially "attention-grabbing" about fearful facial expressions that is not shared with other negative, threat-related expressions like anger (although see Morales et al., 2017).

Another possibility is that low-level perceptual features of fearful facial expressions, such as wide eyes, elicit infant attention. Interestingly, however, 7-month-olds allocate more attention (i.e., longer looking times; larger Nc responses) to happy than fearful eyes (Jessen & Grossmann, 2014, 2016; Krol, Monakhov, et al., 2015). Also, in attentional disengagement tasks, 7-month-olds are slower to shift their attention to a peripheral target when presented with fearful facial expressions, compared to neutral facial expressions with wide, "fearful" eyes (Peltola et al., 2009). Thus, while wide eyes may elicit attention, this feature may not be the sole explanation for the "fear bias."

A more likely explanation for the "fear bias" is that fear facial expressions are unfamiliar. Young infants are rarely exposed to these expressions (Malatesta & Haviland, 1982) and caregivers have described prototypical fear displays as "unnatural" or "uncharacteristic of their normal behavior" (Camras & Sachs, 1991; Rosen, Adamson, & Bakeman, 1992). Direct

evidence also suggests that infants view fearful facial expressions as "novel." For example, in an attentional disengagement task, 7-month-olds were equally likely to fixate on fearful facial expressions compared to a non-emotional, "novel" facial expression (i.e., lips closed, cheeks blown full of air, eyes open; (Peltola, Leppänen, Palokangas, & Hietanen, 2008). In addition, the "fear bias" relates to positive maternal emotionality (de Haan et al., 2004), suggesting that infants are attentive to facial expressions that are not typically encountered in their daily lives. Finally, a few studies report that the "fear bias" declines around 11- to 12-months of age (Peltola et al., 2013), presumably as infants gain more experience with these expressions (Xie et al., 2019).

1.2.4 *Summary*

Taken together, the findings indicate that infants reliably discriminate between positive (happy) and negative facial expressions (fear, anger, sadness) by around 5-months of age. The ability to discriminate between positive and negative vocal and body expressions also develops around this time. However, it is unclear whether infants at any age can discriminate between different negative emotional expressions at a behavioral or neural level. This research question has largely been ignored in the looking-time literature, and the ERP findings are inconsistent. Moreover, although infants show heightened attention to fearful relative to happy expressions, there is little evidence that they discriminate between fear and other negative expressions.

Despite the lack of concrete evidence for within-valence discrimination, classical emotion theories have interpreted the discrimination findings as support for an early-emerging preparedness for emotion understanding, particularly with regard to fearful facial expressions (Leppänen & Nelson, 2006). However, heightened attention to fear faces does not necessarily mean that infants interpret these expressions as "threatening." Consistent with this interpretation,

one study recently reported that the fear bias at 7 months does not correlate with emotion understanding at 48 months (Peltola, Yrttiaho, & Leppänen, 2018). In contrast, constructionist theories have argued that infants discriminate facial expressions on the basis of isolated perceptual features, without "understanding" the emotional meaning (Barrett, 2017; Lindquist & Gendron, 2013).

Given the reviewed literature, the interpretations made by both theories seem premature. There is currently no empirical metric to determine the nature of infants' responses in looking-time and ERP tasks (Madole & Oakes, 1999). In other words, it is not possible to determine whether infants discriminate emotional expressions based on (a) salient perceptual features alone (e.g., mouth shape), (b) affective meaning alone (e.g., the communicative signal of the expression), or (c) some combination of the two. Discrimination studies, as they are currently designed, are ultimately unable to provide meaningful insights into whether infants have discrete emotion concepts.

1.3 **Emotion Categorization**

Emotion categorization studies provide an additional test of infants' ability to differentiate between discrete facial expressions of emotion. *Emotion categorization* is the ability to group different instances of a facial expression (i.e., multiple people expressing the same emotion) together as members of a category. This ability has been tested using *habituation*/*familiarization* paradigms and, in most instances, static facial expressions. Unlike discrimination studies, in which infants are repeatedly shown facial expressions posed by a *single model/person*, categorization studies use *multiple models/people* expressing one emotion (e.g., happiness). At test, infants are thought to form a category if they (a) do not recover looking time to novel models expressing the familiarized/habituation emotion (e.g., happiness), and (b)

recover looking time to familiar models expressing a different emotion (e.g., fear). To form a category, infants need to attend to the relevant, invariant affective information (i.e., the emotion), while ignoring irrelevant, variable perceptual differences (i.e., the person expressing the emotion). Given the memory demands (i.e., infants need to track which models and emotions were presented during habituation; (Aslin, 2007), emotion categorization studies typically test 7- to 12-month-olds (for work with older infants, see Ruba, Johnson, Harris, & Wilbourn, 2017). Studies with 3- to 6-month-olds have yielded mixed results (Bornstein & Arterberry, 2003; A. J. Caron, Caron, & MacLean, 1988; R. F. Caron, Caron, & Myers, 1982; Serrano, Iglesias, & Loeches, 1992; Walker-Andrews, Krogh-Jespersen, Mayhew, & Coffield, 2011).

1.3.1 *Between-valence*

There is some evidence that 7- to 10-month-olds can form a category of happiness (i.e., after habituation to happy expressions) and differentiate this category from novel anger and fear expressions (A. J. Caron et al., 1988; Kestenbaum & Nelson, 1990; Ludemann, 1991; C. A. Nelson & Dolgin, 1985; C. A. Nelson et al., 1979; Safar & Moulson, 2017). It remains unclear, however, whether 3- to 12-month-olds can differentiate a category of happiness from novel sad expressions at test (A. J. Caron et al., 1988; Lee, Cheal, & Rutherford, 2015; Walker-Andrews et al., 2011). Moreover, some studies fail to find *any* evidence of happy categorization, even in infants as old as 11-months of age (Amso, Fitzgerald, Davidow, Gilhooly, & Tottenham, 2010; A. J. Caron et al., 1988; Phillips, Wagner, Fells, & Lynch, 1990; Schwartz et al., 1985; Serrano, Iglesias, & Loeches, 1995). With respect to negative emotions, 4- to 12-month-olds can sometimes form a category of anger expressions and differentiate this category from happy expressions at test (R. F. Caron, Caron, & Myers, 1985; Lee et al., 2015; Serrano et al., 1995; but see Phillips et al., 1990; Schwartz et al., 1985). However, 6- to 11-month-olds do not seem to

form a category of fearful expressions (Amso et al., 2010; Ludemann & Nelson, 1988; C. A. Nelson & Dolgin, 1985; C. A. Nelson et al., 1979; Safar & Moulson, 2017; but see Cong et al., 2019) or sad expressions (Lee et al., 2015; Walker-Andrews et al., 2011) when presented with happy expressions at test.

In these studies, it is unclear whether infants' categories are based on salient perceptual features (e.g., teeth) alone or affective meaning. To test this question, infants have been presented with happy expressions that vary either in intensity or amount of teeth. Infants at 5- to 12-months of age can form a happy category even when the expressions vary in intensity (Bornstein & Arterberry, 2003; Kotsoni, de Haan, & Johnson, 2001; Lee et al., 2015; Ludemann & Nelson, 1988; but see Cong et al., 2019; Phillips et al., 1990). In contrast, when salient facial features vary systematically between the habituation and test trials, infants use those features as the basis for categorization. Specifically, after habituation to non-toothy happy expressions, 4- to 7-month-olds recover looking time to a novel model expressing toothy happiness (R. F. Caron et al., 1985). However, when the amount of teeth is held constant from habituation to test, 7-month-olds provide evidence of categorization (Kestenbaum & Nelson, 1990). Thus, although infants can categorize perceptually variable instances of an emotion (e.g., small, closed-mouth smiles and big, toothy grins), infants are still sensitive to salient facial features. Although this sensitivity seems to decrease over the first year of life, it is still evident around 10-months of age (R. F. Caron et al., 1985; Ludemann, 1991). It is unknown whether infants older than 10-months continue to be influenced by these perceptual cues.

1.3.2 *Within-valence*

Only a handful of studies have used negative facial expressions during both habituation and test. These studies indicate that 4- to 18-month-olds can form a category of anger (i.e., after

habituation to anger expressions) and differentiate this category from novel sad, fear, and disgust expressions (Ruba et al., 2017; Schwartz et al., 1985; Serrano et al., 1992). Moreover, 10- and 18-month-olds can form a category of disgust and differentiate this category from novel anger expressions at test (Ruba et al., 2017). Findings are mixed as to whether 4- to 6-month-olds can form a category of sadness or fear during habituation (Schwartz et al., 1985; Serrano et al., 1992). Given that infants' emotion categorization abilities are tenuous before 7-months of age (A. J. Caron et al., 1988; R. F. Caron et al., 1982), it is possible that only older infants can form these within-valence categories. On the other hand, in a recent *paired-preference* study, 5-month-olds were sensitive to the categorical boundary between sadness and disgust, as well as sadness and anger (White et al., 2019). In the same study, however, both 5- and 9-month-olds were insensitive to the category boundary between anger and disgust.

1.3.3 *Summary*

The categorization literature provides some evidence that, by 7 months of age, infants can form (a) a category for happiness, and differentiate this category from (some) negative expressions and (b) a category for anger, and differentiate this category from happy expressions. There is also emerging evidence that infants can form categories of discrete negative expressions and differentiate these categories from other negative expressions. From a "classical" standpoint, these findings could be used to argue that infants "understand" discrete facial expressions (Walker-Andrews, 1997). If infants can perceive that multiple people are displaying the same emotion, then these categories might be conceptual (i.e., based on affective meaning). On the other hand, constructionist theories would argue that these categories are still perceptual in nature. Infants may attend to a shared facial feature across models (e.g., scrunched noses on disgust expressions) as the basis for these categories. To date, however, there have been few

systematic efforts to manipulate or control for salient facial features in emotion categorization tasks.

Similar to the emotion *discrimination* literature, it is difficult to discern the nature of infants' responding in *categorization* tasks. If infants understand the affective meaning of discrete facial expressions, then they would likely draw on this information, even if they are still influenced by salient perceptual features of the task. In fact, even though adults have discrete emotion concepts, their emotion categorization is still influenced by facial features (e.g., presence of teeth; Ruba, Wilbourn, Ulrich, & Harris, 2018). Thus, the existent categorization literature cannot answer the question of whether infants have discrete emotion concepts.

1.4 Intermodal Matching

Another test of infants' emotion understanding is *intermodal matching* – the ability to match emotions across expressive modalities. While most research has tested intermodal matching of facial and vocal expressions, some studies have examined face-body matches and voice-body matches. In these studies, infants are typically presented with two dynamic facial expressions side by side (e.g., happy and sad). A vocal expression is played that is congruent with one of the facial expressions. Vocal expressions are usually single words or sentences spoken in an emotional tone, although some studies use musical tones (Phillips et al., 1990) or vowel sounds (Palama, Malsert, & Gentaz, 2018). These vocalizations are presented asynchronously with the facial expressions, to prevent infants from matching based on temporal information alone. If infants are sensitive to the common affective information shared by face and voice, they should look longer at the facial expression that "matches" the auditory cue. Most of this work has involved 5- to 7-month old infants (for studies with older infants, see Flom & Whiteley, 2014; Ogren, Burling, & Johnson, 2018). There is some evidence that infants as young

as 3.5-months can form intermodal matches, but only when the facial and vocal stimuli are familiar (i.e., posed by their mothers; Kahana-Kalman & Walker-Andrews, 2001; Vaillant-Molina, Bahrick, & Flom, 2013).

1.4.1 *Between-valence*

Multiple studies have confirmed that 5- to 12-month-olds can match happy and sad vocalizations/tones to their respective facial expressions (Flom & Whiteley, 2014; Phillips et al., 1990; Walker, 1982; but see Soken & Pick, 1999). One study also suggests that 3.5-month-old infants can form these matches, albeit only when the expressions are posed by their mothers (Kahana-Kalman & Walker-Andrews, 2001). Infants between 5- and 7-months of age can also match happy and angry vocalizations to facial expressions (Grossmann, Striano, & Friederici, 2006; Soken & Pick, 1992, 1999; Vaillant-Molina et al., 2013; Walker-Andrews, 1986; Walker, 1982; but see Palama et al., 2018). Infants between 6- and 24-months of age can also form similar intermodal matches with aggressive and nonaggressive canine faces (Flom, Whipple, & Hyde, 2009). More recently, however, Ogren et al. (2018) reported that 9-month-olds did not form intermodal matches for happy, sad, and angry expressions (when paired with a neutral expression). Unlike previous research, this study controlled for baseline expression preferences, thereby providing a more stringent test of intermodal matching.

Recent research has also compared infants' intermodal matching abilities with body expressions. For example, infants as young as 5-months can match happy and angry body expressions to vocal expressions (Heck et al., 2018; Zieber, Kangas, Hock, & Bhatt, 2014a, 2014b). Infants at this age can form similar matches between happy and angry body expressions to facial expressions (Hock et al., 2017). Finally, at least one ERP study suggests that 8-month-

olds are sensitive to the links between happy and fearful body and facial expressions (Rajhans et al., 2016).

1.4.2 *Within-valence*

Few studies have tested whether infants can form intermodal matches when two negative facial expressions are presented. (Phillips et al., 1990) found that 7-month-olds did not match loud and quiet tones to anger and sad faces, respectively. However, 7-month-olds formed intermodal matches for angry and sad faces when the vocal expressions contained human speech (Soken & Pick, 1999), and 6.5-month-olds match sad and anger facial expressions to body expressions (Hock et al., 2017). Thus, successful intermodal matching might depend on using auditory cues with high ecological validity. Importantly, although infants might match negative emotions *across* the dimension of arousal (anger is high arousal, sadness is low arousal; (Russell, 1980), it is unknown whether they can match negative emotions *within* the dimension of arousal (e.g., anger vs. fear).

1.4.3 *Summary*

In summary, 5- to 12-month-olds have been found to match positive and negative faces to positive and negative vocalizations. There is also some evidence to suggest that infants at this age can match positive and negative body expressions to positive and negative faces/voices. However, because these studies have yet to compare expressions *within one dimension of valence and arousal*, it is not known whether these responses are based on discrete emotions (happy vs. sad). Regardless, from a "classical" standpoint, intermodal matching is assumed to go beyond simple expression discrimination, and instead, signifies "emotion recognition" (Walker-Andrews, 1997). More specifically, it has been argued that infants recognize the common affective information that is communicated across the two modalities.

However, a leaner interpretation cannot be discounted. Infants might have simply learned that certain emotional expressions expressed in different modalities (e.g., a smile and laughter) tend to co-occur in their social environment. Consequently, infants could make these matches without any understanding of the affective meaning shared by the modalities. In support of this possibility, one study found that 7-month-old infants showed larger Nc and Pc (positive component) amplitudes to congruent than incongruent facial-vocal expression pairs (Grossmann et al., 2006; but see Otte, Donkers, Braeken, & Van den Bergh, 2015; Rajhans et al., 2016). As previously mentioned, the Nc is thought to reflect heightened visual attention (de Haan et al., 2003), while the Pc is thought to reflect memory for familiar items (C. A. Nelson et al., 1998). This finding suggests that infants may have been relying on their memory for the learned associations between different emotional modalities.

Even if intermodal matching recruits emotion concept knowledge, the current findings do not refute constructionist emotion views. For instance, infants' ability to match positive and negative emotional expressions across modalities is consistent with the hypothesis that infants' emotion concepts are valence- and arousal-based. However, given that discrete emotions are thought to occur with statistical irregularity (Barrett, 2017), preverbal infants should not form intermodal matches with emotions *within a dimension of valence and arousal* (e.g. fear vs anger). Given that these emotion contrasts have yet to be studied, the current intermodal matching literature cannot address this claim.

1.5 **Event-Emotion Matching**

Recently, researchers have begun to explore another component of infants' emotion understanding: *event-emotion matching* – the ability to match emotional expressions with eliciting events. These studies use the violation-of-expectation (VOE) paradigm (Baillargeon,

Spelke, & Wasserman, 1985). In this paradigm, infants are shown a video of an eliciting event (e.g., receiving a gift) followed by an Emoter expressing a congruent (e.g., happiness) or incongruent emotion (e.g., sadness; for live procedures, see Chiarella & Poulin-Dubois, 2013). Whether an emotional expression is "congruent" is determined by the researchers and cultural norms about whether an emotion is likely to be expressed after a particular event. It is certainly possible to express negative emotional expressions (i.e., sadness) in response to a "positive" event (i.e., receiving a gift). Typically, infants' visual attention to emotional expressions is measured (for a pupil dilation measure, see Hepach & Westermann, 2013). If infants have formed links between emotional expressions and eliciting events, they should look longer at an expression that is incongruent with that event compared to the congruent expression. For example, if infants have formed links between receiving a gift and happiness, they should look longer to a sad than a happy expression. This ability is more advanced than intermodal matching since it is thought to reflect an understanding of the *causes* of facial expressions (Hepach & Westermann, 2013; Reschke, Walle, Flom, & Guenther, 2017).

1.5.1 *Between-valence*

Two studies suggest that, by late in the first year of life, infants can match positive emotional expressions with positive events. Hepach and Westermann (2013) reported that 10- and 14-month-olds expected an Emoter to express happiness, rather than anger, when patting a stuffed animal (i.e., a positive action). Similarly, Skerry and Spelke (2014) found that 8- and 10-month-olds expected an agent to express happiness, rather than sadness, after completing a goal. In this study, the agent was a circle that expressed positive affect by smiling, giggling, and bouncing, or negative affect by frowning, crying, and slowly rocking side-to-side.

Infants do not seem to match negative emotions to negative events until the second year of life. For instance, neither 8- nor 10-month-olds in Skerry and Spelke (2014) expected an agent to express sadness, rather than happiness, after failing to complete a goal. Moreover, in Hepach and Westermann (2013), 14-month-olds, but not 10-month-olds, expected an Emoter to express anger, rather than happiness, when hitting a stuffed animal. Consistent with these findings, Reschke et al. (2017) reported that 12-month-olds expected an Emoter to express (a) sadness or anger, rather than happiness, after fighting over a toy with another person, and (b) happiness, rather than anger, after receiving a toy from another person. Infants did not expect an Emoter to express sadness, rather than happiness, after someone broke the Emoter's toy. Finally, Chiarella and Poulin-Dubois (2013) reported that 18-month-olds, but not 15-month-olds, expected an Emoter to express (a) sadness, rather than happiness, after an object was taken away, and (b) happiness, rather than sadness, after receiving a desired object.

1.5.2 *Within-valence*

To date, only one study has examined whether infants match different negative facial expressions to different negative events. Reschke et al. (2017) reported that 12-month-olds *did not* expect an Emoter to express (a) sadness, rather than anger, after another person broke the Emoter's toy, or (b) anger, rather than sadness, after fighting over a toy with another person. Instead, as noted above, infants made valence-based matches (i.e., infants expected an Emoter to express sadness *or* anger after fighting over a toy). Another recent study, not able to speak to infants' understanding of "basic" emotions, reported that 12- to 23-month-olds can match *positive,* within-valence emotional vocalizations (e.g., "sympathy," "excitement") with different elicitors (e.g., a crying infant, a light-up toy; Wu, Muentener, & Schulz, 2017).

1.5.3 *Summary*

This relatively new body of research suggests that infants can match (a) positive emotions to positive events late in the first year of life, and (b) negative emotions to negative events in the second year of life. A "classical" interpretation of these findings is that infants "understand" something about the causes of discrete emotions. However, similar to the *intermodal matching* literature, it is possible that infants form event-emotion matches through simple associative mechanisms, without "understanding" the emotions or the causal link between emotions and events. In addition, it is unclear whether infants can form event-emotion matches based on discrete emotions, given that no studies have found that infants can match *within-valence* emotional expressions to eliciting events (although see, Wu et al., 2017).

1.6 **Social Referencing**

Social referencing—the ability to use another person's emotional expression to guide one's own behavior (Campos & Stenberg, 1981)—is perhaps the most "advanced" test of infants' emotion understanding. In social referencing paradigms, an experimenter or caregiver expresses an emotion in response to a novel object (e.g., a moving, noise-making toy robot). Other novel stimuli have included live animals (Hornik & Gunnar, 1988), human strangers (Feinman & Lewis, 1983), and the "visual cliff" (Sorce, Emde, Campos, & Klinnert, 1985). Several infant responses have been measured, including approach (e.g., latency to touch object), contact (e.g., duration of touch), and affect (e.g., facial/vocal expressions). It is important to note that, although expressed emotions in these studies tend to be multi-modal (i.e., face, voice, and body), research suggests that the vocal expression, rather than the facial expression, drives infants' social referencing behavior (Kim, Walden, & Knieps, 2010; Mumme, Fernald, & Herrera, 1996; Vaillant-Molina & Bahrick, 2012; Vaish & Striano, 2004).

1.6.1 *Between-valence*

Most studies have compared a happy or neutral expression to a negative expression (for a table of studies, see Vaish et al., 2008). Few differences emerge in 10- to 18-month-old's responses to objects that have been the target of a happy versus a neutral expression (Feinman & Lewis, 1983; Hornik, Risenhoover, & Gunnar, 1987; Mumme & Fernald, 2003; Mumme et al., 1996; Repacholi, 2009). In contrast, numerous studies have indicated that 10- to 24-month-olds are more likely to approach and/or touch the object if the Emoter expresses happiness or neutral affect, but exhibit avoidance (delayed and/or reduced object contact) if the Emoter expresses fear (Blackford & Walden, 1998; Camras & Sachs, 1991; Hirshberg, 1990; Hirshberg & Svejda, 1990; Kim & Kwak, 2011; Kim, Walden, & Knieps, 2010; Klinnert, 1984; Klinnert, Emde, Butterfield, & Campos, 1986; Mumme & Fernald, 2003; Mumme et al., 1996; Rosen et al., 1992; Sorce et al., 1985; Stenberg & Hagekull, 1997; Vaillant-Molina & Bahrick, 2012; Walden & Baxter, 1989; Walden & Ogan, 1988; Zarbatany & Lamb, 1985; although see Leventon & Bauer, 2013; Nichols, Svetlova, & Brownell, 2010).

Similar findings have been obtained for 11- to 18-month-olds with happy or neutral versus disgust expressions (Carver & Vaccaro, 2007; Chiarella & Poulin-Dubois, 2018; Flom & Johnson, 2011; Hertenstein & Campos, 2004; Hornik et al., 1987; Moses, Baldwin, Rosicky, & Tidball, 2001; Repacholi, 1998; Slaughter & McConnell, 2003; although see Leventon & Bauer, 2013; Schieler, Koenig, & Buttelmann, 2018). In addition, 15- and 18-month-olds are less likely to imitate a model's actions that have been the target of sad or angry expressions, compared to happy or neutral expressions (Patzwald, Curley, Hauf, & Elsner, 2018; Repacholi, 2009; Repacholi & Meltzoff, 2007; Repacholi, Meltzoff, Hennings, & Ruba, 2016; Repacholi, Meltzoff, & Olsen, 2008; Repacholi, Meltzoff, Rowe, & Toub, 2014; Repacholi, Meltzoff, Toub,

& Ruba, 2016). Taken together, these findings suggest that, by 10- to 12-months, infants "understand" something about the *meaning* of positive and negative facial expressions.

Most of this research has focused on infants 10 months of age and older. Thus, it is unclear whether younger infants also engage in social referencing. A few studies have failed to find evidence that 6- to 9-month-olds regulate their behavior in response to an adult's happy, fearful, and disgust expressions (Slaughter & McConnell, 2003; Walden & Baxter, 1989; Walden & Ogan, 1988). In contrast, Vaillant-Molina and Bahrick (2012) reported that 5.5-month-olds preferentially touched a toy that had been linked with a happy expression compared to a fearful expression. Infants in this study were habituated to the emotion-object pairings before the behavioral response period, and this increased exposure may have enabled infants to better encode these pairings. In addition, several ERP studies have found that infants in the first year of life, and as young as 3-months, show increased Nc activity to pictures of objects that were previously paired with fear or disgust facial expressions, compared to neutral or happy expressions (Carver & Vaccaro, 2007; Hoehl & Striano, 2010b, 2010a; Hoehl, Wiese, & Striano, 2008; but see Aktar et al., 2016; Leventon & Bauer, 2013). These ERP findings suggest that infants are more attentive to objects that are linked to negative facial expressions. In summary, infants younger than 10-months may engage in social referencing when the tasks are more developmentally appropriate.

1.6.2 *Within-valence*

To date, few social referencing studies have examined infants' responses to within-valence emotions. In a classic study, 12-month-olds were more likely to cross a visual cliff when their mothers posed sad expressions compared to anger and fear expressions (Sorce et al., 1985). Similarly, Martin and colleagues (2008, 2014) reported that 16- to 18-month-olds touched target

objects for shorter durations in response to anger and fear expressions compared to sad expressions. One explanation for these findings is that—in the context of an ambiguous object/situation—high arousal, negative emotions (anger, fear) communicate threat and danger (Shariff & Tracy, 2011), and behavioral avoidance is an appropriate response to both of those emotions (Walle & Campos, 2012). These studies do, however, provide evidence for arousal-based behavioral responses (sadness vs. anger/fear).

One limitation of these (and other) social referencing studies is the use of a relatively limited behavioral coding system (i.e., behaviors coded as either approach or avoidance). Recently, Walle, Reschke, Camras, and Campos (2017) designed a coding system focused on the "goal" of infants' behavioral response (e.g., prosocial responding, relaxed play, social avoidance). Infants (16-, 19-, and 24-month-olds) saw an Emoter displaying sadness, anger, fear, or disgust in response to two events. Compared to the other three negative emotions, 24-month-olds showed greater avoidance of the Emoter when she displayed anger. In addition, 19-month-olds (but not 16- or 24-month-olds) demonstrated more "information seeking" (e.g., alternating their gaze between the object and Emoter) in response to disgust than anger. However, infants' "information seeking" did not differ in response to fear compared to disgust or anger. Thus, the evidence for differential responding to negative emotions was less clear-cut at this younger age.

1.6.3 *Summary*

By 10- to 12-months of age, infants can use another person's positive and negative emotional expressions to regulate their own behavior. According to a classical view of emotion, this suggests that infants "understand" the *meaning* of these emotional expressions. For instance, infants may understand that positive emotions communicate safety and approach, while negative emotions signify danger and avoidance (Shariff & Tracy, 2011).

However, an alternative interpretation is that adults' emotional expressions directly modify infants' own felt emotions and subsequent behavior. In this interpretation, infants would not need to "understand" the emotional expression as a meaningful signal in order to regulate their behavior. Consistent with this contagion hypothesis, some evidence suggests that infants display more negative affect in response to an Emoter's fearful expressions, and more positive affect when the Emoter expresses happiness (Hirshberg & Svejda, 1990; Mumme et al., 1996). However, other studies have failed to find differences in infants' affect, particularly when the Emoter expresses anger or disgust (Hertenstein & Campos, 2004; Repacholi, 2009; Repacholi, Meltzoff, Hennings, et al., 2016).

Further evidence against the contagion hypothesis comes from social referencing studies that have manipulated stimulus ambiguity, Emoter competence, and Emoter attention. For instance, when the experimental stimuli are low in ambiguity, adults' emotional expressions have little or no impact on infants' behavior (Kim & Kwak, 2011; Tamis-LeMonda et al., 2008). Behavioral regulation is also less likely if the Emoter is "incompetent" (Stenberg, 2012, 2013). Finally, infants are less likely to regulate their behavior if the Emoter is not visually attending when the infant has access to the object (Botto & Rochat, 2018; Repacholi et al., 2008, 2014). These modulations suggest that infants' behavioral regulation cannot be reduced to emotional contagion. From a contagion perspective, the adult's expression directly modifies infants' own affective state (e.g., a fearful expression causes the infant to become scared, which in turn inhibits their object exploration). If infants are "catching" the adult's emotion via contagion, then they should regulate their behavior regardless of these manipulated task features. However, this is not the case.

Although social referencing is likely to reflect true "understanding" of emotions, the findings are not inconsistent with the constructionist view that infants have valence- and arousal-based emotion concepts. For instance, Walle et al. (2017) found that 24-month-olds differentially responded to different negative emotions, but at this age, infants are quite verbal. Specifically, emotion labels (e.g., "mad", "angry") are beginning to emerge in infants' productive vocabularies (Ridgeway, Waters, & Kuczaj, 1985). Although no language data were reported in this study, it could be argued that infants' acquired emotion language facilitated their understanding of these discrete emotional expressions. Thus, further research is needed to confirm the role of language in infants' behavioral responses to within-valence emotional expressions.

1.7 Language and Emotion Concept Development

The lack of conclusive evidence for discrete emotion understanding has been used by constructionist theorists to argue that preverbal infants are unable to "interpret" or "perceive" discrete negative emotions, particularly on facial expressions (Lindquist & Gendron, 2013; Widen, 2013). Instead, some of these theorists argue that the acquisition of discrete emotion concepts follows another fundamental developmental achievement: language acquisition. Specifically, the "theory of constructed emotion" argues that emotion words (e.g., "happy") impose a categorical structure on otherwise variable emotional expressions (Barrett, 2017; Barrett et al., 2007). In this way, the word "happy" can refer to toothy and non-toothy smiles, expressed across a variety of individuals and in a myriad of contexts. Without emotion labels to serve as category anchors, naturalistic expressions of "happiness" may not share enough similarities to bind them together as members of the same category (Fugate, 2013). For this reason, infants may not be able to form conceptual categories for discrete emotions until they

have acquired emotion labels (Lindquist & Gendron, 2013; Widen, 2013). As previously noted, studies with preverbal infants have not provided definitive evidence against this hypothesis.

1.7.1 *Language and Emotion Categorization in Children and Adults*

Research with older, verbal children and adults, however, does suggest that language constructs emotion categorization. First, emotion words influence how facial expressions are encoded and remembered (Brooks et al., 2017; Doyle & Lindquist, 2018; Fugate, Gendron, Nakashima, & Barrett, 2018). For example, adults remember facial expressions as angrier when the expressions are previously paired with the word "angry" and happier when paired with the word "happy" (Halberstadt & Niedenthal, 2001). In addition, the inclusion of emotion labels in tasks improves children's and adults' emotion categorization performance (Camras & Allison, 1985; Carroll & Russell, 1996; N. L. Nelson et al., 2018; N. L. Nelson & Russell, 2016; Nook, Lindquist, & Zaki, 2015). For example, when asked to sort facial expressions into different categories, (a) 2- to 7-year-olds are more accurate when the categories are specified by an emotion label (Russell & Widen, 2002; Widen & Russell, 2004), and (b) adults are more accurate after reading instructions that include specific emotion labels (i.e., "you will sort *anger and disgust* expressions" (Ruba et al., 2018). In contrast, reduced accessibility to emotion labels leads to slower and less accurate facial expression categorization in adults (Gendron, Lindquist, Barsalou, & Barrett, 2012; Lindquist, Barrett, Bliss-Moreau, & Russell, 2006; Lindquist, Gendron, Barrett, & Dickerson, 2014). Taken together, these studies suggest that language fundamentally impacts emotion categorization in children and adults.

However, one clear limitation to this research is that children and adults have considerable experience with facial expressions and emotion labels. In particular, emotion labels and concepts are always implicitly available in participants' minds (Lindquist & Gendron, 2013),

and participants may draw on this knowledge during the testing session (N. L. Nelson et al., 2018; Ruba et al., 2018). To address this problem, some studies have examined adults with various neurological deficiencies (Lindquist et al., 2014; Nook et al., 2015) or have presented healthy adults with unfamiliar, non-human faces (Doyle & Lindquist, 2018; Fugate, Gouzoules, & Barrett, 2010). Although insightful, these studies cannot address the question of how language constructs emotion categorization with human facial expressions in typically developing populations. A potential solution is to study preverbal infants. To date, no published work has examined how language influences infants' emotion categories.

1.7.2 *Language and Object Categorization in Infancy*

Nevertheless, over two decades of research has documented how labels influence object categorization in infancy (for a review, see (Ferguson & Waxman, 2017). In a seminal study, (Waxman & Markow, 1995) familiarized 13-month-olds with four objects from either a basic-level category (e.g., cars) or a superordinate category (e.g., vehicles, including cars and airplanes). An experimenter presented and labeled each object with either a *noun* ("look, a *car*") or *no noun* ("look what's here"). After being familiarized with the four objects, infants were shown two new objects in the test phase: a novel object from the familiarized category (e.g., car) and a novel object from an unfamiliar category (e.g., horse). Infants formed a basic-level category (cars) regardless of whether a *noun* or *no noun* was presented during familiarization. However, infants *only* formed a superordinate category (vehicles) when a *noun* was presented. Similar facilitative labeling effects have subsequently been found with basic-level categories (Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2010; LaTourrette & Waxman, 2019), novel objects (Booth & Waxman, 2002; Fulkerson & Haaf, 2006; Havy & Waxman, 2016; Nazzi & Gopnik, 2001; Plunkett, Hu, & Cohen, 2008), and other object properties (e.g., spatial

relationships; Casasola, 2005; Casasola, Bhagwat, & Burke, 2009; Pruden, Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, 2013; Waxman, 1999).

Waxman and Markow (1995) argue that labels are "invitations" to form categories. In fact, research has found that labels are unique in their ability to facilitate categorization, compared to other sounds, such as instrumental music (Roberts & Jacob, 1991), non-linguistic tones (Althaus & Westermann, 2016; Balaban & Waxman, 1997; Ferry et al., 2010; Fulkerson & Waxman, 2007), and nonsensical/backwards human speech (Ferry, Hespos, & Waxman, 2013; Fulkerson & Haaf, 2003). Infants at 12-months of age are also unable to form categories when inconsistent labels are used (i.e., each object is given a different label; Waxman & Braun, 2005). These findings suggest that labels do not facilitate categorization simply by heightening infants' attention to objects (Waxman, 1999). Instead, labels appear to facilitate category formation by highlighting commonalities between objects (for alternative explanations, see (Ferguson & Waxman, 2017). Recent eye tracking and EEG research has confirmed that, for 12-month-olds, labels (a) direct visual attention to perceptual commonalities (Althaus & Mareschal, 2014; Althaus & Plunkett, 2016), and (b) increase neural activity over the visual cortex (Gliga, Volein, & Csibra, 2010). This suggests that labels impact infants' visual processing of objects. With evidence from a connectionist model, Westermann and Mareschal (2013) further hypothesize that labels modify visual perception, so that objects from the same-labeled category are perceived as more similar to one another. This is congruent with findings that labels influence facial expression perception in adults (Brooks et al., 2017; Fugate et al., 2018). Thus, while similar processes between language and categorization are evident at multiple stages of development, it remains to be seen whether language also influences *emotion* categorization in infancy.

1.8 Summary of Existent Research

For over fifty years, developmental psychologists have examined how preverbal infants understand others' facial expressions. The resulting empirical research is clear: infants can differentiate positive and negative facial expressions. By 5-months of age, infants can discriminate one positive facial expression from one negative facial expression, in looking-time and ERP paradigms. By 7-months of age, infants can also (a) form distinct categories of positive and negative facial expressions, and (b) match positive and negative facial expressions to positive and negative vocal expressions, respectively. Emerging research also suggests that infants can discriminate between and form intermodal matches with vocal and body expressions in a similar developmental sequence. Around 12-months of age, infants can (a) match positive and negative emotional expressions to positive and negative eliciting events, respectively, and (b) use another person's positive and negative emotional expressions to determine whether to approach or avoid an ambiguous object. Thus, in the first two years of life, infants display a remarkable capacity to perceive, interpret, and differentially respond to other people's positive versus negative emotional expressions.

However, these studies have largely failed to address whether infants are responding on the basis of valence/arousal or discrete emotions (e.g., happy vs. fear). To answer this question, studies need to compare emotional expressions within one dimension of valence and arousal (e.g., anger vs. fear). Although remarkably few studies have made this comparison, there is some suggestion that infants can discriminate and categorize within-valence (negative) facial expressions (e.g., Ruba et al., 2017; White et al., 2019; Xie et al., 2019). However, it is not possible to determine whether these discrimination and categorization abilities are purely perceptual in nature.

Moreover, the few studies examining more advanced forms of emotion understanding have provided limited evidence as to whether infants understand discrete emotions. Infants seem to form intermodal and event-emotion matches on the basis of valence and/or arousal (e.g., Reschke et al., 2017; Soken & Pick, 1999). Similarly, most social referencing studies have also found that infants respond to others' emotional expressions on the basis of valence and/or arousal (Martin et al., 2014, 2008; Sorce et al., 1985). Although some evidence for discrete behavioral responses has been found with 24-month-olds (Walle et al., 2017), at this age, emotion labels are emerging (Ridgeway et al., 1985). Thus, from the existent research, it remains unclear whether and how infants understand discrete emotions before emotion labels are learned.

1.9 Overview of Dissertation

The following chapters describe three empirical papers that address these existent questions. All papers test preverbal infants in looking-time paradigms. In summary, *Chapter 2* (Ruba, Meltzoff, & Repacholi, 2019) examines whether 14- and 18-month-olds can form event-emotion matches between different negative emotional expressions (e.g., anger vs. disgust) and specific eliciting events (e.g., an unmet goal vs. eating food). *Chapter 3* examines (a) whether 14- and 18-month-olds can form a superordinate category of negative facial expressions (e.g., anger, sadness), and (b) how labels influence this category formation. Finally, *Chapter 4* examines potential developmental changes in event-emotion matching abilities between 10- and 14-months of age. Taken together, these papers provide the first critical empirical tests of infants' understanding of discrete emotional expressions in the first two years of life.

Chapter 2. NEGATIVE EVENT-EMOTION MATCHING

2.1 Introduction

In the past several decades, there has been a growing interest in exploring the nature of infants' emotion concepts, or "conceptual categories". Conceptual emotion categories are a collection of expressive behaviors, causal events, consequences, emotion labels, and appropriate behavioral responses that are considered to relate to specific emotions (Fehr & Russell, 1984; Walle & Campos, 2012; Widen & Russell, 2011). For instance, eating spoiled food can elicit a facial expression with a scrunched nose and gaping mouth, which adults tend to label as "disgust." An appropriate behavioral response for an observer of this expression would be to avoid eating the spoiled food. Several studies have provided evidence that, by the end of the first year of life, infants form conceptual categories of emotions *across* the broad domains of valence (i.e., positive vs. negative) and arousal (i.e., high vs. low) (Martin et al., 2014, 2008; Sorce et al., 1985). However, much less is known about whether infants also form conceptual categories of emotions *within* the same dimension of valence and arousal (e.g., anger vs. fear). In particular, some researchers have argued that preverbal infants are unable to form conceptual categories of within-valence emotions (Lindquist & Gendron, 2013; Widen, 2013). The current experiments examine one aspect of infants' ability to form conceptual categories of emotions: event-emotion matching. Specifically, we explored whether infants match different high arousal, negative emotions (i.e., anger, fear, disgust) to specific eliciting events.

2.1.1 *The Development of Conceptual Emotion Categories*

Initially, infants' emotion categories are likely perceptual in nature, based on specific facial features (Quinn et al., 2011). For example, prototypical disgust faces have scrunched noses, whereas prototypical anger faces have furrowed brows (Ekman & Friesen, 1975). Several

studies have found that infants can use this featural information to form perceptual categories for a range of emotional facial expressions—happiness, sadness, anger, fear, and disgust—by 7- to 12-months of age (Kotsoni et al., 2001; C. A. Nelson et al., 1979; Ruba et al., 2017; Safar & Moulson, 2017). To form a perceptual emotion category, infants need only perceive that multiple people are displaying the same expression by attending to a shared facial feature (e.g., scrunched noses on disgust expressions; Ruba et al., 2017). Thus, these perceptual categorization tasks cannot speak to the nature of infants' *conceptual* emotion categories. Instead, these perceptual categories are thought to undergo a process of "enrichment," through language and experience (Eimas, 1994; Gelman & Markman, 1986; Mandler & McDonough, 1993; Quinn & Eimas, 1997), whereby they transform into conceptual emotion categories (i.e., based on affective meaning).

However, there has been considerable disagreement as to the nature of infants' conceptual emotion categories and when this perceptual to conceptual shift might occur. In particular, some researchers have argued that infants form conceptual categories for different emotions, like happiness, anger, and disgust, in the first year of life (Izard, 1994; C. A. Nelson, 1987; Walker-Andrews, 1997). However, other researchers have argued that preverbal infants only form broad, valence- and arousal-based conceptual categories (Barrett, 2017; Barrett et al., 2007). These broad emotion categories (e.g., positive vs. negative emotions) are thought to gradually transform into narrower categories (e.g., anger vs. disgust) over the first decade of life (Widen, 2013). The acquisition of emotion labels (e.g., "happy," "sad") is thought to play a fundamental role in this process (Barrett, 2017; Lindquist & Gendron, 2013). However, in the developmental psychology literature, it is unclear whether preverbal infants only have broad

conceptual categories of emotions (i.e., based on valence and arousal) or whether they are also beginning to form more narrow emotion categories (i.e., based on different emotions).

One major limitation of the existent research on infants' conceptual emotion categories has been the nature of the emotional stimuli presented to infants. According to the circumplex model of affect (Russell, 1980), emotions can be categorized along two broad dimensions of valence (positive vs. negative) and arousal (high vs. low). For instance, with respect to "basic emotions" (Ekman, 1994, 2017), happiness is positive and high arousal, sadness is negative and low arousal, surprise is neutral and high arousal, and anger, fear, and disgust are negative and high arousal. Specifically, when viewed on the circumplex model, anger, fear, and disgust are all located in the same quadrant, although the relative ratings of each emotion slightly differ (e.g., anger is more negatively valenced than fear, whereas fear is higher in arousal than anger; Widen & Russell, 2008). The vast majority of infancy studies compare emotions *across valence and/or arousal*—for instance, comparing happiness to disgust or sadness to anger (for a review, see (Vaish et al., 2008). However, very few studies have examined whether infants can form conceptual categories for emotions *within valence and arousal* (e.g., comparing anger, fear, and disgust). It is necessary to compare emotions within these dimensions in order to determine whether infants can form narrower conceptual categories based on different emotions.

2.1.2 *Social Referencing and Infants' Conceptual Emotion Categories*

Until fairly recently, most research exploring infants' conceptual emotion categories has focused on social referencing. Social referencing is the process by which infants use another person's emotional expression to regulate their own behavior (Klinnert et al., 1986; Sorce et al., 1985; Walden & Ogan, 1988). Multiple studies have reported that, by 12-months of age, infants will approach an ambiguous object that is the target of a happy (or neutral) expression, but will

avoid an ambiguous object that is the target of a negative emotional expression (e.g., disgust; (Hertenstein & Campos, 2004; Moses et al., 2001; Repacholi, 1998). However, these studies do not disentangle whether infants' behavioral responses reflect broad (e.g., positive vs. negative) or more narrow (e.g., happiness vs. disgust) conceptual emotion categories.

To date, only three social referencing studies have examined infants' responses to emotions within the same dimension of valence and arousal. In a classic study, 12-month-old infants were equally hesitant to cross a visual cliff when their mothers posed anger or fear expressions (Sorce et al., 1985). Consistent with this finding, Martin et al. (2014) reported that even 18-month-old infants did not differentially respond to these two negative emotions. Instead, infants were equally likely to avoid playing with a novel toy that had been the target of an adult's anger or fear expression. However, these results are not surprising given that, in the context of an ambiguous object or situation, expressions of anger, fear, and disgust all communicate threat and danger (Shariff & Tracy, 2011). Consequently, in these contexts, behavioral avoidance is an appropriate response to all three emotions (Walle & Campos, 2012).

In the most comprehensive social referencing study to date, Walle et al. (2017) presented 16-, 19-, and 24-month-olds with an Emoter who expressed one of five emotions (i.e., happiness, sadness, anger, fear, disgust) in two contexts (i.e., finding a novel toy, discovering that a toy was broken). Despite using a detailed coding system that focused on the underlying function (or goal) of infants' behaviors, few differences were found in infants' responses to anger, fear, and disgust. The main finding was that 24-month-olds showed greater avoidance of the Emoter when she displayed anger, compared to disgust and fear. Thus, by 24-months, infants seem to understand something about the "social nature" of the threat conveyed by anger expressions relative to other high arousal, negative emotions. There was also some (albeit more limited)

evidence that younger infants were beginning to differentiate between some of these emotions. Specifically, 19-month-olds (but not 16- or 24-month-olds) demonstrated more "information seeking" (e.g., alternating their gaze between the object and the Emoter) in response to disgust than anger. However, this finding is tempered by the fact that infants in the fear condition engaged in similar amounts of information seeking relative to those in *both* the disgust and the anger conditions. Thus, the evidence for differential responding to negative, high arousal emotions was less clear-cut at this age and the pattern of responding is difficult to interpret. Moreover, it is unclear why this difference in information seeking was evident at 19- but not 24-months of age.

In summary, the social referencing literature suggests that it is not until 19- to 24-months of age that infants begin to show different functional behaviors in response to different negative, high arousal emotions (i.e., "functional affective responding", Walle et al., 2017). However, this does not necessarily mean that infants younger than 19-months of age do not have narrower conceptual categories of emotions. Instead, it is likely that these categories are not fully formed at this point in development. Research suggests that verbal children gradually add different components (e.g., facial/vocal expressions, causes, consequences, etc.) to their conceptual emotion categories over the first decade of life (Widen, 2013). In a similar vein, it might be the case that infants' narrow conceptual emotion categories do not yet include information about functional affective responding.

2.1.3 *Event-Emotion Matching and Infants' Conceptual Emotion Categories*

Recently, researchers have begun to explore whether infants are able match emotions to eliciting events. This research has the potential to shed new light on the nature of infants' conceptual emotion categories. Most of these studies have used variants of the violation-of-

expectation (VOE) procedure (Baillargeon et al., 1985). Infants are shown an event (e.g., a broken toy) followed by an Emoter responding with a congruent emotional expression (e.g., sadness) or an incongruent emotional expression (e.g., happiness). Infants' visual attention (Chiarella & Poulin-Dubois, 2013; Reschke et al., 2017; Skerry & Spelke, 2014) or pupil dilation (Hepach & Westermann, 2013) is then measured to infer their expectations about the Emoter's emotional expression. For example, if infants match a broken-toy event to the emotion of sadness, they should look longer at an emotional expression that is incongruent with that event (e.g., happiness) compared to a congruent, sad expression.

These VOE studies suggest that, late in the first year of life, infants match positive events to positive emotions rather than negative emotions. Specifically, 10-month-olds expect an agent/Emoter to express happiness after completing a goal (Skerry & Spelke, 2014) or when petting a stuffed animal (Hepach & Westermann, 2013). However, in these studies, infants did not match negative events (e.g., failing to complete a goal) to negative emotions (e.g., sadness) rather than positive emotions. In contrast, by 12 months of age, infants expect an Emoter to express *either* sadness or anger, but not happiness, after fighting over a toy with another person (Reschke et al., 2017). In addition, when the incongruent emotion is happiness, 14-month-olds expect an Emoter to express anger when hitting a stuffed animal (Hepach & Westermann, 2013), and 18-month-olds (but not 15-month-olds) expect an Emoter to express sadness after having an object taken away (Chiarella & Poulin-Dubois, 2013). These studies suggest that infants begin to match negative emotions to negative events and positive emotions to positive events sometime in the second year of life.

2.1.4 *Current Studies*

Although there is evidence that infants can make valence-based matches between

emotional expressions and events, it is not known whether infants can also match different negative facial expressions to specific negative events. The current studies are the first to explore this research question by comparing emotional expressions *within the same dimension of valence and arousal* (see Wu et al., 2017). Specifically, we used events that are typically associated with anger, disgust, and fear: all of which are high-arousal, negatively valenced emotions (Russell, 1980). If preverbal infants' conceptual emotion categories are broad, they might match a negative event, such as eating unpleasant food, to any negative, high arousal emotion (e.g., disgust, anger, or fear), rather than a specific negative, high arousal emotion (e.g., disgust). On the other hand, if infants have conceptual categories for different negative emotions, then they should match a particular event (e.g., eating unpleasant food) to a specific negative, high arousal emotion (e.g., disgust), but not other negative, high arousal emotions (e.g., anger and fear).

We tested both 14- and 18-month-old infants given that previous research suggests that infants are able to form negative event-emotion matches sometime during this developmental window (Chiarella & Poulin-Dubois, 2013; Hepach & Westermann, 2013). However, we did not have specific hypotheses with respect to age. Experiment 1 tested infants' ability to match emotional expressions to anger- and disgust-eliciting events. Experiment 2 tested infants' ability to match emotional expressions to a revised disgust-eliciting event and a fear-eliciting event. Experiment 3 aimed to replicate the significant effects that were obtained in the first two experiments.

2.2 **Experiment 1**

The first experiment examined infants' ability to match different negative emotions to events in which the Emoter: (a) tried but failed to obtain an out-of-reach object (*Unmet Goal* event), and (b) tasted a novel food (*New Food* event). After each event, infants saw the Emoter

produce either a congruent or an incongruent emotional expression. For example, after viewing the *Unmet Goal* event, infants in the *Anger* condition saw a congruent emotional expression at test, while infants in the *Disgust* and *Fear* conditions saw an incongruent emotional expression. Infants' looking time to the emotional expression was recorded for each event, with the hypothesis that infants would attend longer to the incongruent emotional expressions.

2.2.1 *Methods*

2.2.1.1 Participants

A power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that a sample size of 144 infants (24 for each age/condition) would be sufficient to detect reliable differences, assuming a medium effect size (f =.25) at the .05 alpha level with a power of .80. This was preselected as the stopping rule for the study. The final sample consisted of 72 (36 female) 14-month-old (M = 14.07 months, SD = .16, range = 13.74 – 14.47) and 72 (36 female) 18-month-old infants (M = 18.05 months, SD = .22, range = 17.62 – 18.48). The study was conducted following APA ethical standards and with the approval of the Institutional Review Board (IRB) at the University of Washington (Approval Number: 50377, Protocol Title: "Emotion Categories Study"). Infants were recruited from a university database of parents who expressed interest in participating in research studies. All infants were healthy, full-term, and normal birth weight. Parents primarily identified their infants as Caucasian (79%) or multiracial (15%). Approximately 8% of infants were identified as Hispanic or Latino. An additional 9 infants (6 14-month-olds, 3 18-month-olds) were tested but excluded from the final analyses for the following reasons: failure to complete the procedure (n = 4; 3 14-month-olds), fussiness that led to difficulties with accurate coding (n = 3; 2 14-month-olds), or computer error (n = 2; 1 14-month-old).

2.2.1.2 Design

Equal numbers of male and female infants were randomly assigned to one of three emotion conditions (between-subjects): *Anger*, *Fear*, or *Disgust* (*n* = 48 per condition, 24 per age). Each infant watched two different videotaped events of an Emoter interacting with objects (within-subjects): the *Unmet Goal* event and the *New Food* event. Infants were first presented with two familiarization trials of one of these events (e.g., *Unmet Goal*). This was followed by a test trial in which the Emoter produced an emotional expression (e.g., anger in the *Anger* condition), and looking time was assessed. Following this test trial, infants were then presented with two familiarization trials of the other event (e.g., *New Food*), followed by a test trial of the same emotional expression (e.g., anger; see Figure 2.1). The order in which the two events were presented was counterbalanced across participants.

This design differs from that employed in classic VOE studies in which infants are familiarized (or habituated) to an event and then, at test, are sequentially presented with a congruent and an incongruent outcome (in a counter-balanced order). A pilot study using that design found significant order effects, whereby infants consistently looked longer to whichever emotion was presented second. In an effort to avoid these emotion order effects, the Emoter's emotional expression was held constant for the two event test trials in the current studies. In the pilot study for the current design, no order effects (i.e., *New Food* first vs. *Unmet Goal* first) were evident.

2.2.1.3 Stimuli

Familiarization trials. The familiarization trials consisted of the two videotaped events in which an adult, female Emoter interacted with objects. Both events began with the Emoter sitting at a table, facing the camera. The Emoter introduced herself by looking at the camera and saying

"Hi baby" in a pleasant tone of voice. Following this introduction, the Emoter interacted with different objects in one of two events. Each event was approximately 30 seconds in length (see Figure 2.1).

In the *New Food* event, the Emoter placed a bowl, spoon, and cereal box on top of the table. She looked at the camera and said, pleasantly to the infant, "I'm going to put some food in my bowl." The Emoter picked up the box and poured some nondescript food into her bowl. She returned to looking at the camera, and said, "I'm going to take a bite." The event ended after she dipped her spoon into the bowl and took a bite of food.

In the *Unmet Goal* event, the Emoter placed a bowl, three balls, and tongs on top of the table. She looked at the camera and said, pleasantly to the infant, "I'm going to put some balls in my bowl." The Emoter picked up the tongs and used them to put two of the balls in the bowl. When she reached for the third ball, she "accidentally" knocked the ball out of reach towards the infant/camera. The Emoter leaned across the table and tried to reach the third ball, saying to the camera, with a neutral facial expression, "I can't reach it." Previous research suggests that young infants understand the goals of an individual who attempts to obtain an out-of-reach object and other unmet goals (Hamlin, Wynn, & Bloom, 2007; Meltzoff, 1995; Warneken & Tomasello, 2007; Woodward, 1998).

Test trials. The test trials were videotapes of the Emoter's emotional expression after each event, which consisted of a facial expression and appropriate vocalization. The onset of the expression occurred after the Emoter ate the food (*New Food*) or after the Emoter unsuccessfully reached for the third ball (*Unmet Goal*). Facial expressions followed the criteria outlined by Ekman and Friesen (1975). *Anger* was expressed with furrowed eyebrows and a tight mouth, *disgust* was expressed with a protruding tongue and scrunched nose, and *fear* was expressed with

raised eyebrows and an open mouth. During the expression, the Emoter maintained her gaze on the spoon (which was pulled away from her mouth) or the ball (which was at the edge of the table). Vocal expressions began with an emotional utterance (e.g., a guttural "ugh" for *anger*, "ewww" for *disgust*, or a sharp "ah" for *fear*) followed by, "That's blicketing. That's so blicketing," spoken in an angry/disgusted/fearful tone. Nonsense words were used to minimize infants' reliance on the lexical content of the vocalization. Thus, it was assumed that infants would rely on the affective tone of the facial and vocal expressions to determine the conveyed emotion, not the semantics of the (nonsense) words. After the Emoter finished her script (approximately 5 s), she maintained her facial expression. The video was frozen at this point, to provide a still-frame of the Emoter's emotional expression. This still-frame was shown for a maximum of 60 s, during which infants' looking behavior was recorded (see "Scoring"). Full videos can be accessed here: https://osf.io/eyujq/?view_only=90be6da30b2842a4b02824bfe47d6cfc (for validation information, see Supplementary Analyses, page 63).

2.2.1.4 Apparatus

Each infant was tested in a small room, divided by an opaque curtain into two sections. In one half of the room, infants sat on their parent's lap approximately 60 cm away from a 48 cm color monitor with audio speakers. A camera was located approximately 10 cm above the monitor, focused on the infant's face to capture their looking behavior. In the other half of the room, behind the curtain, the experimenter operated a laptop computer connected to the test display monitor. A secondary monitor displayed a live feed of the camera focused on the infant's face, from which the experimenter observed infants' looking behavior. Habit 2 software (Oakes,

Sperka, & Cantrell, 2015) was used to present the stimuli, record infants' looking times, and calculate the looking time criteria (described below).

2.2.1.5 Procedure

After obtaining parental consent, infants were seated on their parent's lap in the testing room. During the session, parents looked down and were asked not to speak to their infant or point to the screen. Before each familiarization and test trial, an "attention-getter" (a blue flashing, chiming circle) attracted infants' attention to the monitor. The experimenter began each trial when the infant was looking at the monitor. Infants were shown two familiarization trials of the *Unmet Goal* or the *New Food* event (counterbalanced across infants). After two familiarization trials, infants were shown the Emoter's emotional expression, and infants' looking to the still frame of the Emoter's facial expression was recorded. For a look to be counted, infants had to look continuously for at least two seconds. The test trial played until infants looked away for more than two continuous seconds or until the 60 s trial ended. The same procedure was followed for the second event and emotion test trial.

Following the testing session, parents reported whether their infants had the following emotion words in their receptive and productive vocabularies: "anger/mad", "scared/afraid", and "disgusted." Virtually all infants in the sample did not verbally produce these emotion labels (see Table 2.1). A minority of infants were reported to understand the words "anger/mad" (n = 40; 28%), "scared/afraid" (n = 26, 18%), and "disgusted" (n = 9, 6%).

2.2.1.6 Scoring

Infants' looking behavior was live-coded by a trained research assistant. For each event type, this coding began at the end of the Emoter's vocal expression. Because the online coder was aware of the emotion the infant was currently viewing, a second trained research assistant

re-coded 100% of the videotapes offline, without sound. The coder was kept fully blind as to the participant's experimental condition and which emotion was presented to the infant. Reliability between the live and naïve coder was excellent, $r = .98$, $p < .001$. Identical results were obtained using the online and offline coding (analyses with the offline reliability coding are reported below).

2.2.1.7 Hypotheses and Analysis Plan

Between-subjects analyses were planned separately for each event. If infants are able to match different negative emotions to specific events, they should look longer at the expression when it is incongruent with each event, compared to when it is congruent. Thus, after viewing the *Unmet Goal* event, infants should attend longer to the *Disgust* and *Fear* expressions relative to the *Anger* expression. On the other hand, after viewing the *New Food* event, infants should attend longer to the *Anger* and *Fear* emotional expressions relative to the *Disgust* expressions.

2.2.2 *Results*

Preliminary analyses suggested that the looking-time data were significantly and positively skewed (*ps* < .005). Based on recommendations in the literature (Csibra, Hernik, Mascaro, Tatone, & Lengyel, 2016), the data were log-transformed. For ease of interpretation, reported means and standard deviations are the untransformed looking times (in seconds). All infants (i.e., across age and emotion conditions) attended to the entirety of the familiarization trials. A 3 (Emotion: anger / fear /disgust) x 2 (Age: 14-months / 18-months) x 2 (Event Order: new food first / unmet goal first) ANOVA was conducted separately for each event (see Table 2.2 for looking time means and standard deviations). The reported results were unchanged when Total Emotion Vocabulary (i.e., whether infants understood the words "anger," "fear," or "disgust;" scored from 0 to 3) was entered as a covariate.

2.2.2.1 Unmet Goal Event

A significant main effect of Age, $F(1, 132) = 4.51$ $p = .035$, $\eta_p^2 = .03$, revealed that the 18-month-olds attended significantly longer to the emotional expressions ($M = 31.85$ s, $SD = 13.34$) compared to the 14-month-olds ($M = 25.66$ s, $SD = 11.41$). As expected, a significant main effect of Emotion also emerged, $F(2, 132) = 4.43$ $p = .014$, $\eta_p^2 = .06$. Follow-up comparisons revealed that infants attended significantly less to the *Anger* expression compared to the *Disgust* expression, $t(84.95) = 2.40$, $p = .019$, $d = .40$. Infants also attended significantly less to the *Anger* expression compared to the *Fear* expression, $t(87.62) = 2.38$, $p = .019$, $d = .43$. Looking time to the *Disgust* expression and the *Fear* expression did not differ, $t(94) = .05$, $p > .25$, $d = .03$.

This main effect was qualified by a significant Emotion x Order interaction, $F(2, 132) = 5.30$, $p = .006$, $\eta_p^2 = .07$ (for additional analysis of this order effect, see Supplementary Analyses, page 65). There were no other significant main effects or interactions: Order, $F(1, 132) = .01$, $p > .25$, $\eta_p^2 < .01$; Age x Order, $F(1, 132) = .21$, $p > .25$, $\eta_p^2 < .01$; Age x Emotion, $F(2, 132) = .08$, $p > .25$, $\eta_p^2 < .01$; Age x Order x Emotion, $F(2, 132) = .10$, $p > .25$, $\eta_p^2 < .01$.

2.2.2.2 New Food Event

A significant main effect of Order, $F(1, 132) = 8.00$, $p = .005$, $\eta_p^2 = .06$, revealed that infants attended significantly longer to the emotional expressions when the *New Food* event was presented first ($M = 32.94$ s, $SD = 14.23$) compared to when it was presented after the *Unmet Goal* event ($M = 26.25$ s, $SD = 13.23$). A significant Order x Emotion, $F(2, 132) = 4.58$, $p = .011$, $\eta_p^2 = .07$, and Age x Order x Emotion interaction also emerged, $F(2, 132) = 5.73$, $p = .005$, $\eta_p^2 = .08$ (see Supplementary Analyses, page 66). There were no other significant main effects or interactions: Age, $F(1, 132) = 3.42$, $p = .07$, $\eta_p^2 = .03$; Emotion, $F(2, 132) = .85$, $p > .25$, $\eta_p^2 <$

.01; Age x Order, $F(1, 132) = 1.20$, $p > .25$, $\eta_p^2 = .01$; Age x Emotion, $F(2, 132) = .88$, $p > .25$, $\eta_p^2 = .01$.

2.2.3 *Discussion*

After the *Unmet Goal* event, infants attended significantly longer to the incongruent *Disgust* and *Fear* expressions than to the congruent *Anger* expression. This is in line with our hypothesis that infants would expect the Emoter to express anger, rather than disgust or fear, after failing to complete a goal. These results suggest that, by 14-months of age, infants match events involving unmet goals to anger expressions. After the *New Food* event, neither 14- nor 18-month-old infants showed differences in their looking time to the three expressions. Thus, infants at this age did not match a food related event to a disgust expression.

One explanation for the lack of predicted findings in the *New Food* event is that infants did not understand that the Emoter was trying a *new* food. Because she willingly served herself the food, infants may have assumed that this was a familiar food that the Emoter liked or desired. Consequently, infants may have viewed the Emoter's subsequent disgust expression as incongruent or unexpected. To explore this possibility, we created a different *New Food* event for Experiment 2. This event included a second female adult (hereafter, the "Actor"), who fed the Emoter the food. In this second experiment, we also created a fear-congruent event (*Strange Toy*) to examine whether infants are able to match events to fearful expressions.

2.3 **Experiment 2**

2.3.1 *Methods*

2.3.1.1 Participants

The sample consisted of 72 (36 female) 14-month-old ($M = 14.10$ months,

SD = .17, range = 13.74 – 14.47) and 72 (36 female) 18-month-old infants (*M* = 18.09 months, *SD* = .21, range = 17.62 – 18.48). Participants were recruited in the same manner as Experiment 1. Parents primarily identified their infants as Caucasian (77%) or multiracial (19%). Approximately 6% of infants were identified as Hispanic or Latino. One additional 14-month-old was tested but excluded from final analyses for fussiness that led to difficulties with accurate coding.

2.3.1.2 Design

The basic design was the same as Experiment 1.

2.3.1.3 Stimuli

Familiarization trials. The familiarization trials involved two videotaped events of two adult females, an "Actor" and an "Emoter," interacting with objects. Both events began with the Actor and Emoter sitting at a table, facing each other. The Emoter introduced herself to the infant by looking at the camera and saying "Hi baby" in a pleasant tone of voice. Then, the Emoter and Actor introduced themselves to each other and interacted with different objects in one of two events (described below). Each event was approximately 15 s in length (see Figure 2.2).

In the *New Food* event, the Actor placed a spoon and bowl on the table and said to the Emoter, "I have some food, would you like a bite?" The Emoter responded, "I would." Then, the Actor dipped the spoon into the bowl and brought the food to the Emoter's mouth. The event ended when the spoon was in the Emoter's mouth. In the *Strange Toy* event, the Actor placed a Jack-in-the-box toy on the table, and said to the Emoter, "I have a toy, do you want to see?" The Emoter responded, "I would like to see." Then, the Actor cranked the handle on the toy, producing music, as the Emoter watched. The event ended when the toy jumped out of the box.

Test trials. The test trials were videotapes of the Emoter's emotional expression after each event. The onset of the Emoter's emotional expression occurred after she was fed the food (*New Food*) or after the object popped out of the box (*Strange Toy*). Facial and vocal expressions were displayed in the same manner described in Experiment 1. During the emotional expression, the Emoter maintained her gaze on the spoon and bowl (which was pulled away from her mouth) or the toy (which was on the table). These test videos were cropped so that only the Emoter and the object (i.e., spoon/bowl, toy) were present in the frame. Thus, the Actor was not present in the test trial video. Full videos can be accessed here: https://osf.io/eyujq/?view_only=90be6da30b2842a4b02824bfe47d6cfc (for validation information, see Supplementary Analyses, page 64).

2.3.1.4 Apparatus, Procedure, and Scoring

The apparatus, procedure, and scoring were identical to Experiment 1. A second trained research assistant recoded 100% of the tapes offline, without sound. Reliability was excellent, $r = .99$, $p < .001$. Identical results are obtained using the online and offline coding (analyses with the offline reliability coding are reported below).

Similar to Experiment 1, virtually all infants in the sample did not verbally produce the emotion labels "anger/mad", "scared/afraid", or "disgusted" (see Table 2.1). A minority of infants were reported to understand the words "anger/mad" ($n = 38$; 26%), "scared/afraid" ($n = 18$; 13%), and "disgusted" ($n = 5$; 3%).

2.3.1.5 Hypotheses and Analysis Plan

Between-subjects analyses were planned separately for each event. Similar to Experiment 1, if infants are able to match different negative emotions to specific events, they should look longer at the expression when it is incongruent with each event, compared to when it is

congruent. Thus, after viewing the *New Food* event, infants should attend longer to the *Anger* and *Fear* emotional expressions relative to the *Disgust* expressions. On the other hand, after viewing the *Strange Toy* event, infants should attend longer to the *Anger* and *Disgust* expressions relative to the *Fear* expression.

2.3.2 *Results*

As with Experiment 1, the data were log-transformed, but reported means and standard deviations are the untransformed looking times (in seconds). All infants (100%), across ages and conditions, attended to the entirety of the familiarization events. A 3 (Emotion: anger / fear /disgust) x 2 (Age: 14-months / 18-months) x 2 (Order: new food first / unmet goal first) ANOVA was conducted separately for each event (see Table 3 for looking time means and standard deviations). The reported results were unchanged when Total Emotion Vocabulary was entered as a covariate. See

Table 2.3 for relevant cell means (and SD).

2.3.2.1 New Food Event

A significant main effect of Emotion emerged, $F(2, 132) = 3.54$, $p = .032$, $\eta_p^2 = .05$. As predicted, infants attended significantly less to the congruent *Disgust* expression compared to the *Anger* expression, $t(94) = 2.51$, $p = .014$, $d = .60$, and the *Fear* expression, $t(94) = 2.15$, $p = .034$, $d = .57$. Infants did not differ in their looking times to the *Anger* and *Fear* expressions, $t(94) = .24$, $p > .25$, $d = .02$.

There were no other significant main effects or interactions: Age, $F(1, 132) = 1.73$, $p = .19$, $\eta_p^2 = .01$; Order, $F(1, 132) = .08$, $p > .25$, $\eta_p^2 < .01$; Age x Order, $F(1, 132) = .01$, $p > .25$, $\eta_p^2 < .01$; Age x Emotion, $F(2, 132) = 2.34$, $p = .10$, $\eta_p^2 = .03$; Order x Emotion, $F(2, 132) = .82$, $p > .25$, $\eta_p^2 = .01$; Age x Order x Emotion, $F(2, 132) = 1.00$, $p > .25$, $\eta_p^2 = .02$.

2.3.2.2 Strange Toy Event

A significant main effect of Age, $F(1, 132) = 6.87$, $p = .010$, $\eta_p^2 = .05$, revealed that the 18-month-olds attended significantly longer to the emotional expressions ($M = 33.15$ s, $SD = 12.88$) compared to the 14-month-olds ($M = 28.32$ s, $SD = 14.18$). There were no other significant main effects or interactions: Order, $F(1, 132) = .58$, $p > .25$, $\eta_p^2 < .01$; Emotion, $F(2, 132) = .18$, $p > .25$, $\eta_p^2 < .01$; Age x Order, $F(1, 132) = .09$, $p > .25$, $\eta_p^2 < .01$; Age x Emotion, $F(2, 132) = 1.40$, $p = .25$, $\eta_p^2 = .02$; Order x Emotion, $F(2, 132) = .62$, $p > .25$, $\eta_p^2 = .01$; Age x Order x Emotion, $F(2, 132) = .42$, $p > .25$, $\eta_p^2 < .01$.

2.3.3 *Discussion*

Unlike Experiment 1, infants in Experiment 2 matched disgust expressions to an event in which an adult was exposed to a novel food. Using the revised *New Food* event, we found that infants attended longer to the incongruent emotions of *Anger* and *Fear*, compared to the

congruent emotion of *Disgust*. Thus, infants matched the tasting of new food with disgust, specifically, rather than other negative, high arousal emotions. However, the results suggest that infants did not match fearful expressions to an event in which an adult was exposed to an unfamiliar object.

Experiment 3 aimed to replicate the significant Emotion effects obtained in Experiments 1 and 2. Thus, infants were shown the *Unmet Goal* event (from Experiment 1) and the revised *New Food* event (from Experiment 2) followed by either *Anger* or *Disgust* expressions. Given that there were no significant Age x Emotion interactions in the first two experiments, only 14-month-olds were tested in this final experiment

2.4 **Experiment 3**

2.4.1 *Methods*

2.4.1.1 Participants

The sample consisted of 48 (24 female) 14-month-old (M = 14.06 months, SD = .21 months, range = 13.45 – 14.47). Participants were recruited in the same manner as Experiment 1. Parents primarily identified their infants as Caucasian (85%) or multiracial (13%). Approximately 4% of infants were identified as Hispanic or Latino. Two additional infants were tested but excluded from final analyses for fussiness that led to difficulties with accurate coding.

2.4.1.2 Design

The basic design was the same as Experiment 1. Equal numbers of male and female infants were randomly assigned to one of two emotion conditions (between-subjects): *Anger* or *Disgust* (n = 24 per condition).

2.4.1.3 Stimuli

The familiarization trials consisted of the *Unmet Goal* event from Experiment 1 and the revised *New Food* event from Experiment 2. Infants saw either *Anger* or *Disgust* expressions during the test trials.

2.4.1.4 Apparatus, Procedure, and Scoring

The apparatus, procedure, and scoring were identical to Experiment 1. A second trained research assistant recoded 100% of the tapes offline, without sound. Reliability was excellent, $r = .99$, $p < .001$. Identical results are obtained using the online and offline coding (analyses with the offline reliability coding are reported below).

Similar to Experiment 1 and 2, virtually all infants in the sample did not verbally produce labels for the emotions of anger and disgust (see Table 2.1). A minority of infants were reported to understand the words "anger/mad" ($n = 9$; 19%) and "disgusted" ($n = 4$; 8%).

2.4.1.5 Hypotheses and Analysis Plan

We hypothesized that the significant main effects of Emotion obtained in Experiments 1 and 2 would be replicated in a new sample of 14-month-old infants. Between-subjects analyses were planned separately for each event. Thus, after viewing the revised *New Food* event, we expected infants to attend longer to the *Anger* expression relative to the *Disgust* expression. On the other hand, after viewing the *Unmet Goal* event, we expected infants to attend longer to the *Disgust* expression relative to the *Anger* expression.

2.4.2 *Results*

As with Experiment 1 and 2, the data were log-transformed, but reported means and standard deviations are the untransformed looking times (in seconds). All infants (100%), across conditions, attended to the entirety of the familiarization events. A 2 (Emotion: anger / disgust) x

2 (Order: new food first / unmet goal first) ANOVA was conducted separately for each event. The reported results were unchanged when Total Emotion Vocabulary was entered as a covariate.

2.4.2.1 New Food Event

A significant main effect of Emotion, $F(1, 44) = 4.13$, $p = .048$, $\eta_p^2 = .09$, revealed that infants attended significantly less to the *Disgust* expression ($M = 28.64$s, $SD = 15.50$) compared to the *Anger* expression ($M = 34.93$s, $SD = 12.38$). This main effect was qualified by a significant Order x Emotion interaction, $F(1, 44) = 4.36$, $p = .043$, $\eta_p^2 = .09$ (see Supplementary Analyses, page 67). There was no significant main effect of Order, $F(1, 44) = .65$, $p > .25$, $\eta_p^2 = .02$.

2.4.2.2 Unmet Goal Event

Counter to our hypothesis, infants did not attend significantly less to the *Anger* expression ($M = 28.17$s, $SD = 11.60$) compared to the *Disgust* expression ($M = 30.06$s, $SD = 17.93$), $F(1, 44) = .19$, $p > .25$, $\eta_p^2 < .01$. There were no significant effects related to the order in which the event was presented: Order, $F(1, 44) = 2.39$, $p = .13$, $\eta_p^2 = .05$; Order x Emotion, $F(1, 44) = .03$, $p > .25$, $\eta_p^2 < .01$.

2.4.3 *Discussion*

Experiment 3 partially replicated the results of the prior two experiments. Similar to Experiment 2, we found that 14-month-old infants matched a disgust expression to an event in which an adult was exposed to a novel food. However, Experiment 3 did not replicate the effects from the *Unmet Goal* event in Experiment 1. Unlike Experiment 1, infants did not match an anger expression to an event where an adult failed to meet a goal.

2.5 General Discussion

The current studies are the first to directly address the question of whether infants are able to form event-emotion matches for different high arousal, negative emotions (e.g., anger vs. disgust). Moreover, virtually all of the previous studies examining infants' conceptual emotion categories have tested emotional expressions *across the dimensions of valence and/or arousal*. The current experiments begin to fill this theoretically important gap in the literature by comparing three emotions from the *same dimensions of valence and arousal*: anger, disgust, and fear. Taken together, the results indicate that by 14-months of age, infants are able to match *some* of these negative, high arousal emotions to specific eliciting events. However, the findings also suggest that there might be different developmental trajectories for different negative emotions.

In two experiments, we found that infants as young as 14 months of age expected an Emoter to express disgust, rather than anger or fear, after being exposed to a new food. This effect only appeared with an event in which an Emoter was fed a bite of food by another person (Experiments 2 and 3). The effect was not evident when the event involved an Emoter eating a bite of food that she served herself (Experiment 1). As discussed previously, one explanation for these different findings is that the original *New Food* event in Experiment 1 was ambiguous. Another explanation is that infants are better able to understand emotions when they are expressed in interpersonal contexts (Reschke et al., 2017; Walle & Campos, 2012).

In Experiment 1, we also found that 14- and 18-month-old infants expected an Emoter to express anger, rather than disgust or fear, after failing to complete a goal. However, in Experiment 3, 14-month-olds did not form this match. One interpretation of these inconsistent findings is that Experiment 3 (n = 24 infants per emotion condition) was underpowered. In Experiment 1, there were twice as many infants (n = 48 14- and 18-month-olds in each emotion

condition). However, the Emotion effect was significant ($p < .05$) in Experiment 1 when only the 14-month-old data ($n = 24$) were analyzed. An alternative explanation is that, at 14-months of age, infants are only beginning to link anger with unmet goals. Consequently, the effects may be weak and somewhat unreliable at this early point in development. However, given the findings from Experiment 1, this linkage may be more firmly in place by 18-months of age.

Neither the 14- nor the 18-month-olds expected an Emoter to express fear, rather than disgust or anger, after encountering an unfamiliar toy. One possible explanation is that the *Strange Toy* event was ambiguous, leading infants to view anger, disgust, and fear as equally plausible responses to the Jack-in-the-box. Anger could be a congruent emotion if the Emoter did not like or was annoyed by the noise of the toy. Likewise, disgust could also be congruent if infants conflated that emotion with "dislike." Future research should examine infants' understanding of fear using other types of events that infants may view as prototypical elicitors (e.g., snakes, a person encountering a steep cliff; (DeLoache & LoBue, 2009; Sorce et al., 1985). Another possibility is that fear is a later emerging emotion category than disgust and anger. It is noteworthy that in previous habituation/familiarization looking-time studies, infants typically show sustained attention to facial displays of fear, even after habituation to these expressions (e.g., Kotsoni et al., 2001; C. A. Nelson et al., 1979). This suggests that fearful expressions may be particularly novel or attention-getting for infants. In line with this, caregivers have described fearful expressions as "unnatural" and "uncharacteristic of their normal behavior" (Camras & Sachs, 1991; Rosen et al., 1992). In addition, it has been theorized that infants do not experience fear themselves until sometime in the second half of the first year of life, while expressions of anger and disgust are thought to emerge earlier in development (Lewis, 2016).

The fact that infants matched disgust to a novel food event is also consistent with what is known about infants' everyday experience with this emotion. For instance, as infants engage in more independent exploration in the second year of life, parents commonly express disgust in response to the child touching and mouthing certain objects and substances (Stevenson, Oaten, Case, Repacholi, & Wagland, 2010). Moreover, infants frequently display disgust expressions themselves when they are introduced to new foods (Rozin & Fallon, 1987). Thus, by 14- to 18-months of age, infants have had multiple opportunities to learn the associations between expressions of disgust and novel foods.

On the other hand, if these types of experiences are important, then it seems surprising that 14-month-olds did not reliably match anger to unmet goals. Anger expressions are thought to be especially salient for infants during the second year of life (e.g., Grossmann et al., 2007; Ruba et al., 2017). With the onset of crawling and walking, infants are increasingly exposed to other people's expressions of anger (e.g., Campos et al., 2000), and, as parents exert more control over their child's behavior, infants increasingly express anger/frustration themselves (Saarni, Campos, Camras, & Witherington, 2007). These experiences should be sufficient to provide the basis for infants to learn the association between unmet goals and anger. Ultimately, more work on event-emotion matching is needed to determine if disgust has developmental precedence over fear and anger and, if so, whether this is based on differential personal experience with these emotions and events.

2.5.1 *Implications for the Development of Conceptual Emotion Categories*

There has been much debate over the nature of infants' conceptual emotion categories. In particular, some researchers have argued that infants form narrow conceptual categories for different emotions, like happiness, anger, and disgust, in the first year of life (e.g., C. A. Nelson,

1987; Walker-Andrews, 1997). Others have argued that preverbal infants only have broad, valence- and arousal-based conceptual categories (Barrett, 2017; Barrett et al., 2007). In particular, these researchers have argued that conceptual categories for different negative emotions (e.g., anger vs. disgust vs. fear) cannot be acquired before children have learned emotion labels (Barrett, 2017)—a case of language sculpting thought (or in this case emotions). Emotion labels (e.g., "anger") are thought to bind these variable instances of an emotion together into our "commonsense" adult emotion category. Without emotion verbal labels to do this work of binding, it is argued that emotional expressions are too perceptually variable for children to identify them as belonging to a emotion category. For this reason, it is thought that preverbal infants, who do not have emotion labels, do not interpret emotional expressions in terms of narrow categories (Barrett, 2017; Lindquist & Gendron, 2013; Widen, 2013). Given that the majority of infants in our sample did not have the labels "anger," "fear," or "disgust" in their vocabularies (see Table 2.1), one might predict that they would be unable to match different negative, high arousal emotions to specific eliciting events. Therefore, it is noteworthy that preverbal infants as young as 14-months of age expected an Emoter to express disgust, rather than anger or fear, after being exposed to a new food. This finding suggests that it may indeed be possible for infants to begin forming narrow conceptual categories for some emotions (i.e., disgust) before learning emotion labels.

On the other hand, it is likely that, at this point in development, infants do not have fully formed emotion concepts. Although infants seem to be incorporating information about "emotion events/causes" into their early category of disgust by 14 months of age, other components may not emerge until after the acquisition of emotion language (Widen, 2013). For instance, the work of Walle et al. (2017) suggests that it is not until about 19- to 24-months of age that infants begin

to incorporate information about functional affective responding into their category of disgust. It is noteworthy that emotion labels are emerging in infants' productive vocabularies at this age (Ridgeway et al., 1985). Thus, future work should explore the links between language and emotion categories in these older infants. Although the current studies did not find that infants' looking time varied with their emotion vocabulary, future research could explicitly analyze these questions with larger sample sizes.

It is important to note that the effects in these three experiments were small. This is perhaps not surprising given that looking time studies more generally, as well as those that test event-emotion matching specifically (e.g., Wu et al., 2017), also report small effects (for a discussion, see Oakes, 2017). Furthermore, in our studies, infants had to make distinctions between negative emotional expressions that had a high degree of perceptual similarity (e.g., the emotions activate similar facial features) and conceptual similarity (e.g., all were threat-relevant emotions). Even older children and adults struggle to distinguish these particular emotions (e.g., Ruba et al., 2018; Widen, 2013). In addition, matching negative emotions to specific events may be an emerging ability at 14 months of age. Thus, the relative immaturity of this ability combined with the inherently difficult nature of the task may explain why (a) the *Unmet Goal* event failed to replicate in Experiment 3 among the 14-month-olds, and (b) neither 14- nor 18-month-olds matched fearful expressions to the *Strange Toy* event in Experiment 2.

In summary, this research adds to the small body of literature exploring preverbal infants' ability to match emotions to events. By testing three emotions within the same dimension of valence and arousal, the current studies were able to explore whether infants' event-emotion matches reflect relatively narrow conceptual categories for different emotions (i.e., anger vs. fear vs. disgust). To determine whether infants' conceptual emotion categories are broad versus

narrow, it is *necessary* to use emotional expressions within the same dimension of valence and arousal. However, this test alone is not *sufficient* to determine the boundaries of infants' emotion categories. For instance, an infant may show a different response to anger expressed in a social context (towards another person) compared to anger expressed in a non-social context (towards an object), yet infants may not view these instances of "anger" as belonging to separate categories. It is important to replicate the current findings with a wider array of events in order to more precisely determine the nature of infants' conceptual emotion categories.

The findings presented here represent an important step toward understanding the nature of infants' conceptual emotion categories, but much is still unknown. For instance, it is unclear whether infants' responses reflect (a) learned associations between different emotional displays (e.g., happiness) and specific events (e.g., receiving a desired object), or (b) an understanding of the causal link between emotions and events. Future research will also need to determine whether infants more readily form event-emotion matches when they have personally experienced these pairings in their daily lives (e.g., eating novel foods and disgust expressions) compared to pairings that are relatively unfamiliar (e.g., jumping over a barrier and sad expressions; Skerry & Spelke, 2014). In addition, further research is needed to determine *how* emotion concepts are acquired during infancy and the extent to which these might be impacted by parental socialization (within and across cultures). Future research should also continue to explore the nature of infants' emotion categories by examining different components, such as behavioral consequences and functional affective responding. Nonetheless, the current research illustrates the importance of testing a variety of emotional expressions in order to more fully understand the nature of infants' conceptual emotion categories.

2.6 **Supplementary Analyses**

2.6.1 *Emotion Validation Methods*

Sixty university undergraduates were recruited from the Psychology Participant Pool to validate the emotional expressions used in the current studies. Participants were given course credit in exchange for their ratings.

The videos were validated in an online survey. After consenting to participate, participants viewed one videotaped emotional expression (i.e., anger, fear, disgust) from one of the four events used in the current studies (i.e., *Unmet Goal, New Food 1, New Food 2, Strange Toy*). The expression was presented facially and vocally. Participants answered two questions to measure the *valence* of the emotional expression and the *arousal* level of the emotional expression. After answering the questions for one video, the next video played until all twelve videos were rated. The videos were presented in a random order.

The valence and arousal questions were adapted from the Self-Assessment Manikin (SAM; Bradley & Lang, 1994). We chose the SAM given that it is a non-verbal, pictorial measure, which reduces participants' reliance on language. Participants were asked, "How does this person feel?" and were prompted to select one of five pictures of a cartoon mannequin. For the valence ratings, the mannequin's facial expression ranged from a large frown (i.e., very negative) to a large smile (i.e., very positive). For the arousal ratings, the mannequin's expression ranged from closed eyes (i.e., very low arousal) to open eyes with an exploding chest (i.e., very high arousal). For analysis, participants' picture selections were recoded from 1 (i.e., very positive / high arousal) to 5 (i.e., very negative / low arousal). Ratings for each of the emotions were compared to "neutral valence" and "medium arousal" (i.e., a score of "3") in one-

sample t-tests. Planned paired samples t-tests also compared the three emotions for the valence and arousal ratings. Means and standard deviations for the ratings are presented in

Table 2.4.

2.6.1.1 Unmet Goal Event (Experiment 1 and 3)

All three expressions were rated as significantly more negative compared to neutral: anger, $t(58) = 10.13$, $p < .001$; disgust, $t(58) = 14.53$, $p < .001$; fear, $t(58) = 5.63$, $p < .001$. The fear expressions were rated as significantly less negative than the anger expressions, $t(58) = 2.94$, $p = .005$, and the disgust expressions, $t(58) = 3.62$, $p = .001$. Ratings for the anger and disgust expressions did not differ, $t(58) = .71$, $p > .25$.

The anger, $t(58) = 3.37$, $p < .001$, and fear expressions, $t(58) = 4.90$, $p < .001$, were rated as significantly more arousing compared to medium arousal. Disgust expressions did not differ in arousal from "medium", $t(58) = .74$, $p > .25$. The disgust expressions were rated as significantly lower in arousal than the anger expressions, $t(58) = 3.38$, $p = .001$, and the fear expressions, $t(58) = 4.65$, $p < .001$. Ratings for the anger and fear expressions did not differ, $t(58) = .87$, $p > .25$.

2.6.1.2 Original New Food Event (Experiment 1)

All three emotional expressions were rated as significantly more negative compared to neutral: anger, $t(58) = 13.46$, $p < .001$; disgust, $t(58) = 11.88$, $p < .001$; fear, $t(58) = 2.14$, $p = .037$. The fear expressions were rated as significantly less negative than the anger expressions, $t(58) = 6.11$, $p < .001$, and the disgust expressions, $t(58) = 5.10$, $p < .001$. Ratings for the anger and disgust expressions did not differ, $t(58) = 1.66$, $p = .10$.

The anger expressions, $t(58) = 3.50$, $p < .001$, and fear expressions, $t(58) = 5.51$, $p < .001$, were rated as significantly more arousing compared to medium arousal. Disgust expressions did not differ in arousal from "medium", $t(58) = .28$, $p > .25$. The disgust expressions were rated as significantly lower in arousal than the anger expressions, $t(58) = 3.37$, $p = .001$, and the fear

expressions, $t(58) = 4.50$, $p < .001$. Ratings for the anger and fear expressions did not differ, $t(58) = 1.26$, $p = .21$.

2.6.1.3 Revised New Food Event (Experiments 2 and 3)

There were no significant differences between the emotional expressions: anger compared to disgust, $t(58) = .80$, $p > 25$; anger compared to fear, $t(58) = .81$, $p > .25$; disgust compared to fear, $t(58) = 1.75$, $p = .09$. All three emotional expressions were also rated as significantly more negative compared to neutral: anger, $t(58) = 11.89$, $p < .001$; disgust, $t(58) = 14.49$, $p < .001$; fear, $t(58) = 10.34$, $p < .001$.

Only the fear expressions were rated as significantly more arousing compared to medium arousal, $t(58) = 5.77$, $p < .001$. Disgust expressions, $t(58) = .13$, $p > .25$, and anger expressions, $t(58) = .43$, $p > .25$, did not differ in arousal from "medium". The fear expressions were rated as significantly higher in arousal than the anger expressions, $t(58) = 4.09$, $p < .001$, and the disgust expressions, $t(58) = 4.65$, $p < .001$. Ratings for the anger and disgust expressions did not differ, $t(58) = .20$, $p > .25$.

2.6.1.4 Strange Toy Event (Experiment 2)

All three emotional expressions were rated as significantly more negative compared to neutral: anger, $t(58) = 12.39$, $p < .001$; disgust, $t(58) = 16.80$, $p < .001$; fear, $t(58) = 10.54$, $p < .001$. There were no significant differences between the emotional expressions: anger compared to disgust, $t(58) = .46$, $p > 25$; anger compared to fear, $t(58) = .40$, $p > .25$; disgust compared to fear, $t(58) = .93$, $p > .25$.

Only the fear expressions were rated as significantly more arousing compared to medium arousal, $t(58) = 6.09$, $p < .001$. Disgust expressions, $t(58) = .26$, $p > .25$, and anger expressions, $t(58) = 1.85$, $p = .07$, did not differ in arousal from "medium." The fear expressions were rated as

significantly higher in arousal than the anger expressions, $t(58) = 2.78$, $p = .007$, and the disgust expressions, $t(58) = 5.32$, $p < .001$. Ratings for the anger and disgust expressions did not differ, $t(58) = 1.36$, $p = .18$.

2.6.2 *Order Effects*

Means and standard deviations for infants' looking times are presented in Table 2.5.

2.6.2.1 Unmet Goal Event (Experiment 1)

A significant Emotion x Order interaction, $F(2, 132) = 5.30$, $p = .006$, $\eta_p^2 = .07$ emerged. When the *Unmet Goal* event was presented first (before the *New Food* event), there were no significant differences between infants' looking time to the three emotional expressions, all *ps* > .05. However, when the *Unmet Goal* event was presented second (after the *New Food* event), infants attended significantly less to the *Anger* expression compared to the *Disgust* expression, $t(39.22) = 3.61$, $p = .001$. Infants also attended significantly less to the *Anger* expression compared to the *Fear* expression, $t(37.12) = 2.65$, $p = .010$. Looking time to the *Disgust* expression and the *Fear* expression did not differ, $t(47) = 1.42$, $p = .16$.

2.6.2.2 New Food Event (Experiment 1)

A significant Order x Emotion, $F(2, 132) = 4.58$, $p = .011$, $\eta_p^2 = .07$, and Age x Order x Emotion interaction emerged, $F(2, 132) = 5.73$, $p = .005$, $\eta_p^2 = .08$. Follow-up Emotion x Order ANOVAs were conducted separately by Age.

For the 14-month-olds, there were no significant main effects or interactions: Order, $F(1, 66) = 1.79$, $p = .19$, $\eta_p^2 = .03$; Emotion, $F(2, 66) = 2.05$, $p = .14$, $\eta_p^2 = .06$; Order x Emotion, $F(2, 66) = .02$, $p > .25$, $\eta_p^2 < .01$. For the 18-month-olds, a significant main effect of Order, $F(1, 66) = 6.63$, $p = .012$, $\eta_p^2 = .09$, revealed that infants attended significantly longer to the emotional expressions when the *New Food* event was presented first ($M = 37.34$ s, $SD = 14.32$) compared

to when it was presented after the *Unmet Goal* event (M = 28.00 s, SD = 15.52). This main effect was qualified by a significant Order x Emotion interaction, $F(2, 132) = 8.71$, $p < .001$, $\eta_p^2 = .21$. There was not a significant main effect of Emotion, $F(2, 66) < .01$, $p > .25$, $\eta_p^2 < .01$.

When the *New Food* event was presented first, 18-month-old infants attended significantly *more* to the *Disgust* expression compared to the *Anger*, $t(12.89) = 2.61$, $p = .022$, and the *Fear* expressions, $t(22) = 2.43$, $p = .024$. These findings were the opposite of what we predicted. As expected, looking time to the *Anger* and the *Fear* expressions did not differ, $t(22) = 1.02$, $p = .20$. In contrast, when the *New Food* event was presented second (i.e., after the *Unmet Goal* event), infants attended significantly *less* to the *Disgust* expression compared to the *Anger* expression, $t(22) = 2.93$, $p = .008$. On the other hand, looking times to the *Disgust* and *Fear* expressions did not differ, $t(22) = 1.36$, $p = .19$. Looking times to the *Anger* and *Fear* expressions also did not differ, $t(22) = 1.65$ $p = .11$.

2.6.2.3 New Food Event (Experiment 3)

A significant Order x Emotion interaction, $F(1, 44) = 4.36$, $p = .043$, $\eta_p^2 = .09$, emerged. Follow-up comparisons revealed that when the *New Food* event was presented first, infants' looking time to the *Disgust* and *Anger* expressions did not differ, $t(22) = .04$, $p > .25$. However, when the *New Food* event was presented second (after the *Unmet Goal* event), infants attended less to the *Disgust* expression compared to the *Anger* expression, $t(18.11) = 3.09$, $p = .005$.

2.7 Tables and Figures

Table 2.1. Total number of infants (and proportion of infants in sample) who were reported to have the following emotion labels in their receptive and productive vocabularies

	Experiment 1			Experiment 2			Experiment 3
	14 mos.	18 mos.	Total	14 mos.	18 mos.	Total	Total (14 mos.)
Receptive							
"Angry/Mad"	14 (.19)	26 (.36)	40 (.28)	16 (.22)	22 (.31)	38 (.26)	9 (.19)
"Scared/Afraid"	8 (.11)	18 (.25)	26 (.18)	7 (.10)	11 (.15)	18 (.13)	4 (.08)
"Disgusted"	2 (.03)	7 (.10)	9 (.06)	3 (.04)	2 (.03)	5 (.03)	1 (.02)
Productive							
"Angry/Mad"	1 (.01)	1 (.01)	2 (.01)	0 (.00)	1 (.01)	1 (.01)	2 (.03)
"Scared/Afraid"	0 (.00)	1 (.01)	1 (.01)	0 (.00)	2 (.03)	2 (.01)	1 (.01)
"Disgusted"	0 (.00)	0 (.00)	00 (.00)	0 (.00)	0 (.00)	0 (.00)	0 (.00)

Table 2.2. Experiment 1: Relevant cell means (and *SD*) of total looking time (in seconds) to the test events.

Event	Age	Cell *n*	Anger	Disgust	Fear
Unmet Goal	All	48	23.72 (14.77)	29.70 (14.75)	30.18 (15.52)
	14 only	24	19.32 (10.81)	27.13 (14.39)	27.66 (14.57)
	18 only	24	28.11 (16.98)	32.27 (14.96)	32.70 (16.34)
New Food (1)	All	48	28.08 (13.90)	30.30 (15.06)	30.54 (13.46)
	14 only	24	23.07 (10.45)	27.07 (11.33)	29.68 (13.12)
	18 only	24	33.09 (15.28)	33.53 (17.71)	31.40 (14.03)

Table 2.3. Experiment 2: Relevant cell means (and *SD*) of total looking time (in seconds) to the test events.

Event	Age	Cell *n*	Anger	Disgust	Fear
New Food (2)	All	48	35.31 (16.83)	26.19 (13.23)	34.92 (17.18)
	14 only	24	36.54 (18.18)	25.90 (12.72)	28.98 (17.13)
	18 only	24	34.07 (15.66)	26.48 (13.99)	40.85 (15.36)
Strange Toy	All	48	30.75 (16.56)	28.92 (14.33)	28.33 (15.69)
	14 only	24	30.64 (17.77)	25.44 (14.22)	22.42 (12.96)
	18 only	24	30.86 (15.65)	32.41 (13.87)	34.24 (16.19)

Table 2.4. Means and standard deviations of validation ratings. Ratings range from 1 (i.e., very positive / high arousal) to 5 (i.e., very negative / low arousal).

	Valence Ratings			**Arousal Ratings**		
	Anger	Disgust	Fear	Anger	Disgust	Fear
Unmet Goal	4.05 (.80)	4.14 (.60)	3.66 (.90)	2.56 (1.00)	3.08 (.88)	2.41 (.93)
New Food 1	4.22 (.70)	4.03 (.67)	3.29 (1.04)	2.54 (1.00)	3.03 (.95)	2.31 (.97)
New Food 2	4.10 (.71)	4.19 (.63)	4.00 (.74)	2.95 (.92)	2.98 (.97)	2.29 (.95)
Strange Toy	4.15 (.72)	4.20 (.55)	4.10 (.80)	2.73 (1.13)	2.97 (1.00)	2.22 (.98)

Table 2.5. Relevant cell means (and *SD*) of total looking time (in seconds) to the test events. Note: Only 14-month-olds were tested in Experiment 3.

Event (Experiment)	Age	Order	Cell *n*	Anger	Disgust	Fear
Unmet Goal (Exp. 1)	All	Goal First	24	27.11 (14.06)	23.28 (10.26)	31.23 (15.47)
	All	Food First	24	20.33 (14.97)	36.12 (15.92)	29.22 (15.83)
New Food (Exp. 1)	18 only	Goal First	12	36.40 (15.13)	20.37 (13.15)	27.24 (14.94)
	18 only	Food First	12	29.78 (15.34)	46.68 (10.24)	35.55 (12.28)
New Food (Exp. 3)	14 only	Goal First	12	37.38 (11.41)	23.04 (12.40)	N/A
	14 only	Food First	12	32.49 (13.30)	34.23 (16.74)	N/A

Figure 2.1. Experiment 1 design. Test Trials are depicted for each Condition: (a) Anger, (b) Disgust, and (c) Fear.

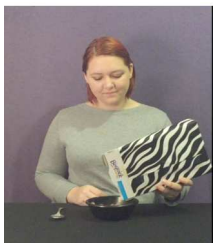
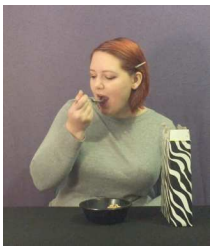
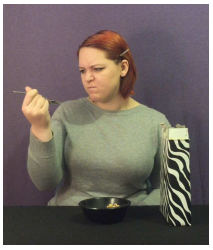
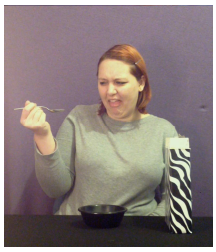
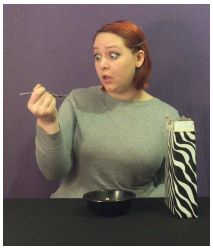
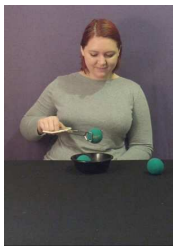
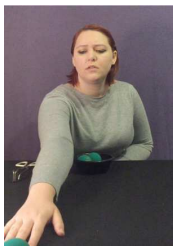
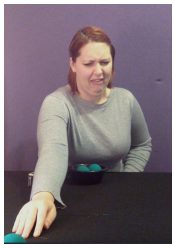
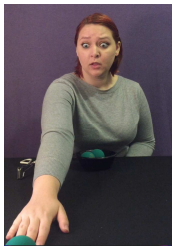
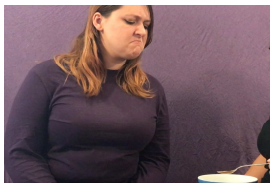
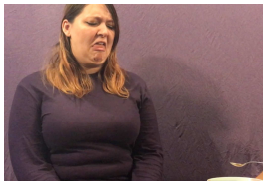
Event	Familiarization Trials (x2)	Test Trials
New Food Event	 	(a)  (b)  (c) 
Unmet Goal Event	 	(a)  (b)  (c) 

Figure 2.2. Experiment 2 design. Test Trials are depicted for each Condition: (a) Anger, (b) Disgust, and (c) Fear.

Event	Familiarization Trials (x2)	Test Trials
New Food Event	 	(a)  (b)  (c) 
Strange Toy Event	 	(a)  (b)  (c) 

Chapter 3. LABELS FACILITATE EMOTION CATEGORIZATION

3.1 Introduction

Accurate recognition of emotional (facial) expressions is an essential social skill. Children who can correctly identify and appropriately respond to others' emotions have improved social-emotional, academic, and occupational outcomes (Grinspan, Hemphill, & Nowicki, 2003; Schultz, Izard, Ackerman, & Youngstrom, 2001). For this reason, researchers have extensively documented the development of emotion categorization. A large body of research suggests that preschoolers initially categorize emotional expressions in terms of broad dimensions, such as positive and negative valence (Russell, 1994). Throughout the first decade of life, these broad/superordinate categories (e.g., negative valence) slowly differentiate into narrow/basic-level categories (e.g., sadness, anger, fear, and disgust; Widen & Russell, 2008). According to the "theory of constructed emotion," this differentiation process is language-dependent, driven by the acquisition of emotion words/labels (e.g., "anger"; Barrett, 2017; Lindquist & Gendron, 2013). While this process has been well-documented with verbal children, much less research has examined how emotion categorization emerges and develops in infancy. The current studies are the first to test (a) whether infants form superordinate categories for negative emotional expressions, and (b) how language influences emotion categorization in infancy.

3.1.1 *Infant Emotion Categorization*

Prior studies on emotion categorization in infancy have largely examined whether infants can form basic-level categories of different emotional expressions. In these studies, infants are habituated/familiarized to pictures of multiple models (i.e., people) expressing one emotion (e.g., happiness). At test, infants form an emotion category if they (a) do not recover looking time to

novel models expressing the habituation emotion (e.g., happiness), and (b) recover looking time to familiar models expressing a novel emotion (e.g., fear). The most consistent finding is that, by 7-months of age, infants can form a basic-level category of happiness (i.e., after habituation to happy expressions) and differentiate this category from sad, angry, and fearful expressions at test (Amso et al., 2010; Bornstein & Arterberry, 2003; Cong et al., 2019; Kotsoni et al., 2001; Safar & Moulson, 2017; Walker-Andrews et al., 2011). Infants at this age can also form a basic-level category of anger during habituation and differentiate this category from happy, sad, fear, and disgust expressions at test (R. F. Caron et al., 1985; Lee et al., 2015; Ruba et al., 2017; Serrano et al., 1995). Infants likely form these basic-level categories on the basis of salient facial features (e.g., "nose scrunch") rather than on the conceptual meanings of the emotions (e.g., the avoidance of food; Ruba et al., 2017).

Although infants in the first year of life are beginning to form *basic-level* emotion categories, it is unclear whether infants also form *superordinate* categories of emotional expressions. Superordinate categories are based on abstract features, such as valence. For instance, while infants may categorize anger expressions as distinct from disgust expressions, they may not recognize that both anger and disgust are "negative" emotions. To date, only one study has examined whether infants can form superordinate categories of emotional expressions. Ludemann (1991) habituated 7- and 10-month-olds to four people expressing happy and pleasant-surprise expressions. At test, 10-month-olds (but not 7-month-olds) looked longer at novel people expressing anger and fear compared to novel people expressing the habituated emotions of happiness and pleasant-surprise. At first glance, these results suggest that the older infants may have formed a category of positive valence (happiness and pleasant-surprise) that was distinct from each of the two negative emotions. However, an alternative interpretation is

that infants simply perceived that the happy and surprised expressions were *perceptually* distinct from the anger and fearful expressions. Quinn et al. (2011) suggest that in order to determine whether infants formed a superordinate emotion category (based on positive valence), a *different* positive emotion (e.g., interest) would need to be included in the test trials. In a similar vein, infants could be habituated to two negative emotions (e.g., disgust, sadness) and presented with a novel, negative emotion at test (e.g., anger) to determine whether they have formed a category based on negative valence. The current studies explore this latter possibility.

There is reason to believe that infants can form a superordinate category of negative valence. Social referencing studies, for instance, have found that infants differentially respond to other people's emotions based on valence. Specifically, by 12-months of age, infants will approach an ambiguous object that is the target of a happy (or neutral) expression, but will avoid an ambiguous object that is the target of a negative emotional expression (e.g., disgust; (Hertenstein & Campos, 2004; Moses et al., 2001; Repacholi, 1998). More importantly, infants seem to respond with behavioral avoidance to a variety of negative emotional expressions, such as anger, disgust, and fear (Martin et al., 2014; Sorce et al., 1985; Walle et al., 2017). Consistent with these findings, the "theory of constructed emotion" (Barrett, 2017) has proposed that infants initially group these different emotions into a superordinate category of negative valence. However, with the exception of Ludemann (1991), no prior research has tested whether infants can form these valence-based emotion categories.

3.1.2 *Does Language Influence Emotion Categorization in Infancy?*

The current studies also explore whether and how language influences emotion categorization in infancy. The importance of language to emotion categorization has been extensively supported by research with verbal children and adults. For instance, the inclusion of

emotion labels in sorting tasks improves emotion categorization accuracy (e.g., Nook et al., 2015; Russell & Widen, 2002; Widen & Russell, 2004), while reduced accessibility to emotion labels leads to slower and less accurate emotion categorization (Gendron et al., 2012; Lindquist et al., 2006, 2014; Ruba et al., 2018). According to the "theory of constructed emotion", children and adults use language as context for the categorization of emotional expressions. In particular, emotion labels (e.g., "happy") facilitate categorization because they impose a categorical structure on otherwise variable emotional expressions (Barrett et al., 2007). For example, the label "anger" can refer to toothy and non-toothy grimaces, expressed in a variety of contexts across different people. Without this label, "anger" emotional expressions may not share enough similarities to group them together as members of the same category (Fugate, 2013; Fugate et al., 2010). It has been argued that language is particularly important for emotion categorization in the second year of life, when emotion labels are first learned (Barrett, 2017).

However, there has been no published work examining whether labels facilitate emotion categorization in infancy. Nevertheless, studies have documented the impact of labels on infants' categorization of objects and object properties (e.g., Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2010). In these studies, infants are familiarized/habituated to different objects from a category (e.g., cars and airplanes), which are presented with a single label (e.g., "vehicle"; Waxman & Markow, 1995). The addition of a label to the familiarization/habituation trials has a facilitative effect on infants' categorization of objects (e.g., Booth & Waxman, 2002; LaTourrette & Waxman, 2019) and spatial relations, such as "containment" (e.g., Casasola, 2005) and "path" (e.g., Pruden, Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, 2013). This facilitative effect appears to be unique to verbal labels, inasmuch as infants do not form these categories when presented with a pure tone sequence or backwards human-speech (Balaban &

Waxman, 1997; Ferry et al., 2013; Fulkerson & Waxman, 2007). One explanation for these effects is that verbal labels prompt infants to search for non-obvious commonalities between objects (Althaus & Mareschal, 2014; Waxman & Markow, 1995). It is possible that similar labeling effects may be found when facial expressions are used as stimuli. However, while facial expressions of emotion are observable and "object-like" (e.g., a smile), these expressions are also an indicator of an unobservable internal state (e.g., happiness). Given this additional complexity, it is unclear whether labels would facilitate categorization in the same manner for objects, object properties, and facial expressions of emotion.

3.1.3 *Current Studies*

The first aim of the current studies was to determine whether infants perceive that different negative emotional expressions (anger, sadness, disgust) all belong to a superordinate category of negative valence. The second aim of the current studies was to explore whether verbal labels influence infants' emotion categories. According to the "theory of constructed emotion" (Barrett, 2017) (a) preverbal infants can form superordinate categories of emotional expressions, and (b) verbal labels facilitate the *division* of these superordinate categories into basic-level categories (e.g., anger, disgust). We expected to find these effects in the current studies.

Across four studies, 14- and 18-month-olds were tested in a habituation-categorization paradigm. These ages were chosen since emotion labels begin to appear in infants' productive vocabularies around 18-months (Ridgeway et al., 1985). Fourteen-month-olds were tested to capture any developmental differences in emotion categorization prior to the use of emotion labels. At least one study has found that labels facilitate categorization of novel objects for 18-month-olds, but not for 14-month-olds (Booth & Waxman, 2002). Negative emotional

expressions were examined, given that four of the five emotions that are considered "universal" are negative valence (i.e., sadness, anger, fear, disgust; Ekman, 1994, 2017). Negative emotions provide a wealth of social information for infants, and these expressions are particularly important in terms of survival (for a review, see Vaish et al., 2008). Consequently, it would be adaptive for infants to be able to form negative emotion categories.

3.2 **Experiment 1**

Experiment 1 tested whether infants could form a superordinate category of negative valence. Infants were habituated to two different negative emotions (e.g., disgust and sadness) expressed by three people. After habituation, infants were shown four test trials. Forming an abstract, superordinate category requires that infants treat a novel instance of the abstract category as familiar (Casasola, 2005b). In the current studies, if infants formed a superordinate category of negative valence, their looking time to a *negative familiar event* (a person and emotion seen during habituation; e.g., disgust) should not differ from their looking time to a *negative novel face* (a person not seen during habituation, expressing one of the habituation emotions; e.g., sadness) and a *negative novel emotion* (a person seen during habituation expressing a novel, negative emotion; e.g., anger). Infants' looking time to each of these three negative emotions should also be significantly lower than their looking time to a *positive novel emotion* (a person seen during habituation expressing a novel, positive emotion, i.e., happiness). In other words, infants should treat the three negative emotions as belonging to a separate, familiar category compared to the novel, positive emotion. Given the findings in the social referencing literature, and in line with the "theory of constructed emotion", we predicted that infants would form a superordinate category of negative valence.

3.2.1 *Methods*

3.2.1.1 Participants

The participants were 48 (24 female) 14-month-olds (M = 14.08 months, SD = .15 months, range = 13.81 – 14.40 months) and 48 (24 female) 18-month-olds (M = 18.10 months, SD = .19 months, range = 17.72 – 18.41 months). A power analysis indicated that a sample size of 48 infants (24 for each age/condition) would be sufficient to detect reliable differences, assuming a medium effect size (f = .25) at the .05 alpha level with a power of .80. This was pre-selected as the stopping rule for the study. An additional 31 infants (24 18-month-olds) were tested but excluded from the final analyses for the following reasons: failure to meet the habituation criteria, described below (n = 7; 5 18-month-olds); failure to finish the study due to fussiness (n = 15; 14 18-month-olds); and fussiness/inattentiveness that lead to difficulties with accurate coding (n = 9; 5 18-month-olds). To this latter point, the blind, online coder marked the tested infant as likely too fussy and/or inattentive for coding to be reliable. Another blind coder confirmed this decision during secondary offline coding. The high attrition rate for the 18-month-olds is similar to other emotion categorization studies with this age group (Ruba et al., 2017).

Infants were recruited from a university database of parents who expressed interest in having their infants participate in research studies. All infants were healthy, full-term, and had normal birth weight. Infants were primarily identified as Caucasian (81%, n = 78) and multiracial (15%, n = 14). About 7% (n = 7) of infants were identified as Hispanic or Latino. The study was conducted following APA ethical standards and with approval of the Institutional Review Board (IRB) at the University of Washington (Approval Number: 50377, Protocol Title: "Emotion Categories Study"). Infants were randomly assigned to the *Anger-Sad* or the *Disgust-Sad*

conditions.

3.2.1.2 Stimuli

Semi-dynamic events were created in iMovie, using static images from the Radboud Faces Database (for validation information, see Langner et al., 2010). Pictures of neutral, sadness, anger, disgust, and happiness facial expressions were chosen as stimuli. Each event began with a picture of an adult female displaying a neutral expression (Figure 3.1). After 1.5s, a picture of the person's emotional expression (e.g., anger) appeared. This static expression was presented for 3.5s before a black screen appeared, which lasted for 1s. These 6s events were looped five times, without pause, to create a 30s video, which comprised a single trial in the study.

Three of the four "universal" negative emotions—anger, disgust, and sadness—were used in the current studies. Fear was excluded because previous research (e.g., Grossmann & Jessen, 2017; Kotsoni et al., 2001) as well as our own pilot testing suggested that infants have a spontaneous preference for fearful expressions and dishabituate to these faces at test. During the habituation trials, infants viewed either anger and sad (*Anger-Sad* condition) or disgust and sad expressions (*Disgust-Sad* condition). An *Anger-Disgust* condition was not included given that (a) infants tend to form more inclusive categories when there is perceptual overlap among the exemplars (Oakes, Coppage, & Dingel, 1997), and (b) anger and disgust expressions have a high degree of perceptual overlap (Widen & Russell, 2013).

3.2.1.3 Apparatus

Each infant was tested in a small room, divided into two sections by an opaque curtain. In one half of the room, infants sat on their parent's lap approximately 60cm away from a 48cm color computer monitor and audio speakers. A camera was located approximately 10cm above

the monitor and focused on the infant's face to capture their looking behavior. In the other half of the room, behind the curtain, the experimenter sat at a table with a laptop computer (connected to the testing monitor). A secondary monitor displayed a live feed from the camera that was focused on the infant's face. The experimenter used this live feed to record infants' looking behavior during each trial. The Habit 2 software program (Oakes et al., 2015) was used to present the stimuli, record infants' looking times, and calculate the habituation criteria (described below).

3.2.1.4 Procedure

After obtaining parental consent, infants were seated on their parent's lap in the testing room. During the session, parents looked down and were asked not to speak to their infant or point to the screen. Before each habituation and test trial, an "attention-getter" (i.e., a blue flashing, chiming circle) directed infants' attention to the monitor. The experimenter began each trial when the infant was looking at the monitor and recorded the duration of infant's looking behavior during that trial. For a look to be counted, infants had to look continuously for at least 2s. Each habituation and test trial played until infants looked away for more than two continuous seconds or until the 30s trial ended.

Infants first saw a pre-test trial (i.e., plush cow toy rocking back and forth) designed to acclimate them to the task. The subsequent *habituation trials* varied based on condition. In the *Anger-Sad* condition, infants saw three different people expressing anger and sadness, and in the *Disgust-Sad* condition, infants saw three different people expressing disgust and sadness. These six habituation events (i.e., three people, each expressing the two negative emotions) were randomized and presented in blocks. The habituation trials continued until infants' looking time across the last three trials decreased 50% or more from their looking time during the first three

consecutive habituation trials or until 18 habituation trials were presented. Only infants who met the habituation criteria were included in the final analyses.

After the habituation trials, infants were presented with four *test trials.* The *negative familiar event* test trial was a person seen during habituation, expressing one of the habituation emotions (e.g., sad person 1). The *negative novel face* test trial depicted a new person, not seen during habituation, expressing one of the habituation emotions (e.g., anger person 4). The *negative novel emotion* test trial depicted a person seen during habituation expressing a novel, negative emotion (e.g., disgust person 2), which was either disgust (*Anger-Sad* condition) or anger (*Disgust-Sad* condition). The *positive novel emotion* test trial depicted a person seen during habituation expressing a novel, positive emotion, which was always happiness (e.g., happy person 3). The *negative novel emotion* and *positive novel emotion* test trials employed familiar people (seen during habituation), so that infants' responses could be attributed to novelty of the emotion only. The selected familiar/novel negative people were counterbalanced across participants, and the presentation order of the test stimuli was blocked and randomized (see Figure 3.1 for example stimuli).

3.2.1.5 Scoring

Infants' looking behavior was live-coded by a trained research assistant. The coder was blind to which stimuli the infant was currently viewing during the habituation and test trials. A second research assistant, who was also display-blind, re-scored 25% of the tapes ($n = 24$) offline. Reliability was excellent for duration of looking on each trial, $r = .93$, $p < .001$.

3.2.2 *Results*

For each experiment, all of the statistical tests were two-tailed and alpha was set at .05. Fisher's least significant difference (LSD) procedure was employed throughout the analyses.

Thus, follow-up t-tests were only conducted when the omnibus analyses were significant, and no adjustments were made for multiple comparisons.

3.2.2.1 Habituation Phase

To confirm that infants' looking times sufficiently decreased from habituation to test, a 2 (Age) x 2 (Condition) x 2 (Trials: mean of first three habituation trials vs. negative familiar event test trial) mixed-model ANOVA was conducted. This analysis yielded a significant main effect of Age, $F(1, 92) = 122.84$, $p = .050$, $\eta_p^2 = .04$, whereby 18-month-olds looked longer across the trials ($M = 14.63$s, $SD = 3.65$s) than the 14-month-olds ($M = 13.04$s, $SD = 4.16$s). There was also a significant main effect of Trials, $F(1, 92) = 479.44$, $p < .001$, $\eta_p^2 = .84$, and a significant Trials x Condition interaction, $F(1, 92) = 128.31$, $p = .010$, $\eta_p^2 = .07$. There were no other significant effects.

Follow-up analyses, comparing the habituation and the test trials, were conducted to identify the source of the Trials x Condition effect. Paired sample t-tests revealed that infants' looking behavior significantly decreased from habituation to test in the *Anger-Sad,* $t(47) = 12.42$, $p < .001$, $d = 2.15$, and the *Disgust-Sad* conditions, $t(47) = 18.71$, $p < .001$, $d = 3.43$. Hence, infants had not reached the habituation criteria by chance (Oakes, 2010). However, infants in the *Disgust-Sad* condition had significantly lower looking times to the *negative familiar event* ($M =$ 6.04s, $SD = 2.96$s) compared to infants in the *Anger-Sad* condition ($M = 7.95$s, $SD = 5.04$s), $t(75.97) = 2.26$, $p = .026$ $d = .46$. Infants' looking times during the first three habituation trials did not differ between the *Disgust-Sad* condition ($M = 21.36$s, $SD = 5.59$s) and the *Anger-Sad* condition ($M = 19.99$s, $SD = 6.09$s), $t(94) = 1.14$, $p > .25$, $d = .23$. Thus, the decrease in infants' looking times from habituation to test was more marked in the *Disgust-Sad* condition relative to the *Anger-Sad* condition.

3.2.2.2 Test Phase

Infants' looking times during the test trials were analyzed in a 4 (Test Trial) x 2 (Age) x 2 (Condition) mixed-model ANOVA. This analysis yielded a significant main effect of Test Trial, $F(3, 276) = 31.69$, $p < .001$, $\eta_p^2 = .26$. Follow-up comparisons between the test trials were conducted using paired t-tests. These analyses revealed that infants spent significantly less time looking at the *negative familiar event* compared to the *negative novel face* ($p < .001$, $d = .95$), the *negative novel emotion* ($p < .001$, $d = .94$), and the *positive novel emotion* ($p < .001$, $d = 1.34$). This suggests that infants did not form a superordinate category of negative valence. Infants also looked significantly longer at the *positive novel emotion* compared to the *negative novel face* ($p = .008$, $d = .37$) and the *negative novel emotion* ($p = .015$, $d = .32$). Infants' looking behavior to the *negative novel face* and the *negative novel emotion* did not differ ($p > .25$, $d = .04$; see Table 3.1 for cell means). Thus, infants differentiated the three *negative emotion* test trials from the *positive novel emotion.* This pattern of results was evident for both the 14- and 18-month-olds when their data was separately analyzed (see Supplementary Analyses, page 101).

In addition, a significant main effect of Age, $F(1, 92) = 4.92$, $p = .04$, $\eta_p^2 = .05$, revealed that 18-month-olds looked longer at the test trials ($M = 13.49$s, $SD = 5.24$s) compared to the 14-month-olds ($M = 11.35$s, $SD = 4.62$s). Finally, there was a significant main effect of Condition, $F(1, 92) = 9.31$, $p = .003$, $\eta_p^2 = .09$, whereby infants in the *Anger-Sad* condition looked longer to the test trials ($M = 13.89$s, $SD = 5.56$s) compared to infants in the *Disgust-Sad* condition ($M = 10.94$s, $SD = 3.97$s). There were no other significant effects.

3.2.3 *Discussion*

At both ages and across conditions, infants' looking time to the negative familiar event was significantly lower than their looking time to the other two negative emotion test trials (i.e.,

negative novel face and negative novel emotion). Thus, infants registered which event they had seen during habituation, but they did not form a superordinate category of negative valence. This finding was unexpected, given that social referencing research suggests that infants show valence-based behavioral responses to different emotions (e.g., Hertenstein & Campos, 2004; Moses et al., 2001; Repacholi, 1998). The current findings are also inconsistent with predictions made by the "theory of constructed emotion" (Barrett, 2017). As noted previously, this theory argues that infants have superordinate representations of emotional expressions.

Interestingly, infants' looking times for each of the negative emotion test trials was significantly lower than their looking time to the *positive novel emotion* test trial. Thus, infants showed valence-based *discrimination* of the emotional expressions by differentiating each of the three negative emotions (anger, sadness, disgust) from the positive emotion (happiness). This replicates previous findings that infants can discriminate happy expressions from negative facial expressions (e.g., anger, sadness) in the first year of life (e.g.,Bornstein & Arterberry, 2003; Flom & Bahrick, 2007; Montague & Walker-Andrews, 2001).

3.3 **Experiment 2**

Given that infants did not spontaneously form a superordinate category, Experiment 2 tested whether labeling each habituation event with the same novel word (i.e., "toma") would facilitate categorization. We predicted that the addition of a label would help infants form a superordinate category for negative emotions, in the same way that labels can facilitate object and object property categorization (Casasola, 2005b; Pruden et al., 2013; Waxman & Markow, 1995). Specifically, we predicted that: (a) infants' looking time to the *negative familiar event, negative novel face*, and *negative novel emotion* would not differ from one another, and (b) infants' looking times for each of these three negative emotion test trials would be significantly

lower than their looking times to the *positive novel emotion*. A few studies have reported that labels are more likely to facilitate category formation for infants with larger vocabularies (Casasola & Bhagwat, 2007; Nazzi & Gopnik, 2001; Waxman & Markow, 1995; but see Althaus & Plunkett, 2016). Thus, we also examined the relationship between infants' vocabulary size and their emotion categorization in the presence of labels (see Supplementary Analyses, page 104).

3.3.1 *Methods*

3.3.1.1 Participants

The final sample consisted of 64 (32 female) 14-month-olds (M = 14.12 months, SD = .18 months, range = 13.78 – 14.47 months) and 64 (32 female) 18-month-olds (M = 18.06 months, SD = .23 months, range = 17.62 – 18.48 months). Infants were primarily identified as Caucasian (81%, n = 104) and multiracial (13%, n = 17). About 8% (n = 10) of infants were identified as Hispanic or Latino. An additional 23 infants (13 18-month-olds) were tested but excluded from final analyses for the following reasons: failure to meet the habituation criteria (n = 6 18 month-olds), failure to finish the study due to fussiness (n = 14; 6 18-month-olds), and fussiness/inattentiveness during the study (n = 3; 1 18-month-old). The sample size was larger than Experiment 1 in order to conduct exploratory analyses related to infants' language development (see Supplementary Analyses, page 104). Infants were randomly assigned to the *Anger-Sad* condition or to the *Disgust-Sad* condition.

Parental report confirmed that very few of these infants were using emotion labels. Only nine infants (n = 4 18-month-olds) had produced the word "happy," three infants (n = 1 18-month-old) had produced the word "sad," and no infants had produced the words "angry," "scared," or "disgusted" (or synonyms). Thus, the vast majority of infants in this sample did not

have emotion labels in their expressive vocabularies, which is consistent with previous research findings for this age group (e.g., Ridgeway et al., 1985).

3.3.1.2 Stimuli

The visual stimuli were identical to Experiment 1. However, a verbal label was added to each of the six habituation events. The label was a pre-recorded nonsense word (i.e., "toma") spoken by a native English-speaking female using infant-directed speech. In each habituation event, the same novel word was spoken twice after the person's target expression appeared. The novel word was never presented immediately before or during the appearance of the expression. This presentation format increased the likelihood that infants would associate the novel word with the expressions themselves and decreased the likelihood that infants would: (a) associate the word with the expression change, or (b) make causal attributions (e.g., the word caused the person's expression to change). This label was only presented with the habituation trials: the test trials were presented in silence, without labels.

3.3.1.3 Apparatus and Procedure

The apparatus and habituation procedure were identical to Experiment 1. Infants' receptive and expressive vocabularies were measured by parental report via the CDI, English Long Form (Fenson et al., 2007).

3.3.1.4 Scoring

The scoring procedure was identical to Experiment 1. Reliability was excellent (25% of tapes rescored; $n = 32$) for duration of looking on each trial, $r = .96$, $p < .001$.

3.3.2 *Results*

3.3.2.1 Habituation Phase

A 2 (Age) x 2 (Condition) x 2 (Trials) mixed-model ANOVA was conducted. A significant main effect of Trials, $F(1, 126) = 567.02$, $p < .001$, $\eta_p^2 = .82$, revealed that infants looked significantly longer to the first three habituation trials ($M = 25.02$s, $SD = 4.70$s) compared to the *negative familiar event* ($M = 10.86$s, $SD = 6.73$s). There were no other significant effects.

3.3.2.2 Test Phase

Infants' looking times during the test trials were analyzed in a 4 (Test Trial) x 2 (Age) x 2 (Condition) mixed-model ANOVA. Significant main effects of Test Trial, $F(3, 372) = 27.31$, $p < .001$, $\eta_p^2 = .18$, and Condition, $F(1, 124) = 10.86$, $p = .001$, $\eta_p^2 = .08$, were qualified by a significant Test Trial x Condition interaction, $F(3, 372) = 7.05$, $p < .001$, $\eta_p^2 = .05$. In addition, a significant Test Trial x Age interaction emerged, $F(3, 372) = 3.31$, $p = .026$, $\eta_p^2 = .03$. Follow-up paired t-tests revealed that 18-month-olds looked significantly longer at the *negative novel face* test trial compared to the 14-month-olds, $t(122.34) = 2.12$, $p = .036$, $d = .32$. There were no significant age group differences among the other test trials (see Table 3.1 for cell means).

Follow-up analyses to explore the Test Trial x Condition interaction were conducted separately by Condition (see Figure 3.2). For the *Anger-Sad* condition, a significant main effect of Test Trial emerged, $F(3, 186) = 17.12$, $p < .001$, $\eta_p^2 = .22$. Follow-up paired t-tests revealed that infants looked significantly less at the *negative familiar event* compared to the *negative novel face* ($p < .001$, $d = .76$), the *negative novel emotion* ($p < .001$, $d = .88$), and the *positive novel emotion* ($p < .001$, $d = .99$). There were no other significant differences. Thus, as with Experiment 1, infants did not form a superordinate category of negative valence in the *Anger-Sad* condition

For the *Disgust-Sad* condition, a significant main effect of Test Trial also emerged, $F(3, 186) = 17.25$, $p < .001$, $\eta_p^2 = .22$. Follow-up paired t-tests revealed that infants looked significantly longer at the *positive novel emotion* compared to the *negative familiar event* ($p < .001$, $d = 1.03$), the *negative novel face* ($p < .001$, $d = .73$), and the *negative novel emotion* ($p < .001$, $d = .85$). Critically, however, infants' looking to the *negative familiar event* did not differ from the *negative novel face* ($p = .12$, $d = .26$) or the *negative novel emotion* ($p > .25$, $d = .15$), and looking to the *negative novel face* did not differ from the *negative novel emotion* ($p > .25$, $d = .11$). Thus, infants formed a superordinate category of negative valence in the *Disgust-Sad* condition (see Table 3.1 for cell means). For completeness, we also ran the analyses (a) separately for both age groups, and (b) equating the sample size with that of Experiment 1 (see Supplementary Analyses, page 102). The same results were obtained for both ages and when the data from only the first 24 infants (per age) tested in each experimental condition were analyzed.

3.3.2.3 Combined Experiment 1 and Experiment 2 Analysis

To determine whether the addition of a label in Experiment 2 significantly impacted infants' categorization in comparison to Experiment 1, data for the *Disgust-Sad* condition were analyzed in a 4 (Test Trial) x 2 (Age) x 2 (Experiment) mixed-model ANOVA. This analysis revealed a significant main effect of Test Trials, $F(3, 276) = 25.98$, $p < .001$, $\eta_p^2 = .22$, which was qualified by a marginally significant Test Trial x Experiment interaction, $F(3, 276) = 2.26$, $p = .081$, $\eta_p^2 = .02$. This interaction effect lends some support to the conclusion that labels facilitated the formation of a superordinate category in Experiment 2.

3.3.3 *Discussion*

The results of Experiment 2 suggest that adding a novel verbal label to each habituation event facilitated the formation of a superordinate category of negative valence in the *Disgust-Sad*

condition. In this condition, infants' looking times to the *negative familiar event, negative novel face,* and *negative novel emotion* test trials did not differ from one another. Infants' looking times to each of the three *negative* trials were also significantly lower than their looking to the *positive novel emotion* test trial. On the other hand, in the *Anger-Sad* condition, infants did not form a superordinate category of negative valence. Instead, as with Experiment 1, infants attended longer to the *negative novel face* and the *negative novel emotion* relative to the *negative familiar event*. These condition differences are considered further in the General Discussion. Although infants' looking times in the *Disgust-Sad* condition suggest that they formed a superordinate category, this conclusion is tempered by the results of the cross-experiment analysis. When data from Experiments 1 and 2 were analyzed together, the Test Trial x Experiment interaction only approached significance. Thus, the labeling effect requires replication. The findings in the first two experiments are also complicated by the fact there were clear perceptual differences between some of the facial expression stimuli (see Figure 3.1). Specifically, while the anger and sad facial expressions displayed teeth, the disgust expressions did not. Prior research has found that when salient facial features vary systematically between the habituation and test trials, 7-month-olds use these features as the basis for categorization (R. F. Caron et al., 1985; Kestenbaum & Nelson, 1990). Although this sensitivity seems to decrease over time, it is still evident at 10-months of age (R. F. Caron et al., 1985; Ludemann, 1991). It is unknown whether infants older than 10-months continue to be influenced by these perceptual cues. However, there is some evidence that the presence of teeth in facial expressions impacts emotion categorization in adults (Ruba et al., 2018).

To replicate and extend the results of the first two experiments, Experiments 3 and 4 were conducted with expressions that did not display teeth (see Figure 3.3), selected from the

NimStim Set of Facial Expressions (Tottenham et al., 2009). A new expression database was used because the original database (Radboud Face Database; Langner et al., 2010) did not contain disgust or happy expressions lacking teeth. In a pilot study with "toothy" facial expressions (selected from the NimStim Set of Facial Expressions), half of the sample did not meet the habituation criteria. Thus, "non-toothy" facial expressions were used for Experiments 3 and 4. Given that there were no age differences in Experiment 1 and 2, only 14-month-olds were tested in the subsequent experiments. Further, since infants in the *Anger-Sad* condition did not show any evidence of categorization, only the *Disgust-Sad* condition was tested further. Experiment 3 examined whether infants would form a superordinate category of negative valence when the amount of teeth was held constant on the facial expressions.

3.4 **Experiment 3**

3.4.1 *Methods*

3.4.1.1 Participants

The final sample consisted of 24 (14 female) 14-month-olds (M = 14.15 months, SD = .19 months, range = 13.71 – 14.40 months). Participants were recruited in the same manner as Experiment 1. Infants were primarily identified as Caucasian (78%, n = 19) and multiracial (17%, n = 4). About 8% (n = 2) of infants were identified as Hispanic or Latino. An additional 11 infants were tested but excluded from final analyses for the following reasons: failure to meet the habituation criteria (n = 3), failure to finish the study due to fussiness (n = 3), and fussiness or inattentiveness during the study (n = 5).

3.4.1.2 Stimuli

The stimuli were similar to Experiment 1. The key difference was that pictures from the NimStim Set of Facial Expressions (for validation information, see (Tottenham et al., 2009) were

used. In order to eliminate the potential influence of teeth on infants' categorization, pictures were chosen that did not show teeth. Models #07 and #08 were used for the *negative novel face* test event. Models #03, #06, and #09 were used for habituation and all other test events (see Figure 3.3 for pictures of Model #03).

3.4.1.3 Apparatus and Procedure

All infants were tested in the *Disgust-Sad* condition. All other aspects of the apparatus and procedure were identical to Experiment 1.

3.4.1.4 Scoring

The scoring procedure was identical to Experiment 1. Reliability was excellent (50% of tapes rescored; $n = 12$) for duration of looking on each trial, $r = .95$, $p < .001$.

3.4.2 *Results*

3.4.2.1 Habituation Phase

A paired samples t-test confirmed that infants' looking behavior significantly decreased from habituation to test, $t(23) = 4.97$, $p < .001$, $d = 1.60$. Infants had significantly higher looking times during the first three habituation trials ($M = 21.33$s, $SD = 5.39$s) compared to the *negative familiar event* ($M = 11.35$s, $SD = 7.01$s).

3.4.2.2 Test Phase

Infants' looking times during the test trials were analyzed in a repeated-measures ANOVA. This analysis did not yield a significant main effect of Test Trial, $F(3, 69) = 1.61$, $p = .18$, $\eta_p^2 = .07$ (see Table 3.1 for cell means). Thus, infants' looking times did not differ between the four test trials (Figure 3.4).

3.4.3 *Discussion*

Similar to Experiment 1, infants in Experiment 3 did not form a superordinate category of negative valence. However, in contrast to Experiment 1, infants in Experiment 3 did not differentiate (a) the *positive novel emotion* from the *negative emotion* test trials, or (b) the *negative familiar event* from the other test trials. In other words, infants did not discriminate between the happy expression and the negative expressions. Even more surprisingly, infants did not track which event they had seen in the habituation trials.

One possibility is that Experiment 3 was underpowered (n = 24 14-month-olds) relative to Experiment 1 (n = 48 14- and 18-month-olds). However, this is unlikely, given that the 14-month-olds in the *Disgust-Sad* condition in Experiment 1 were able to track which event they had seen during habituation (see Supplementary Analyses, page 102). A more likely explanation for the findings in Experiment 3 is that, in the absence of teeth, all four facial expressions were very perceptually similar. In other words, infants were unable to extract the relevant emotional information in the absence of a salient perceptual cue (e.g., teeth). In Experiment 1, the presence versus absence of teeth may have highlighted the differences between the emotions (i.e., disgust expressions displayed teeth, sad expressions did not), enabling infants to track and differentiate the expressions. Although previous research has suggested that 7-and 10-month-olds will use salient facial features, such as teeth, as the basis for emotion categorization (e.g., R. F. Caron et al., 1985; Kestenbaum & Nelson, 1990), this is the first study to suggest that infants in the second year of life are still sensitive to these salient perceptual cues.

3.5 **Experiment 4**

Experiment 4 aimed to replicate and extend the findings of Experiment 2, that adding a label to each habituation event would facilitate superordinate category formation. Specifically,

we predicted that: (a) infants' looking time to the *negative familiar event, negative novel face*, and *negative novel emotion* would not differ from one another, and (b) infants' looking times for each of these three negative emotion test trials would be significantly lower than their looking times to the *positive novel emotion*. In addition, we predicted that we would find a significant Test Trial x Experiment interaction when data from Experiments 3 and 4 were analyzed together.

3.5.1 *Methods*

3.5.1.1 Participants

The final sample consisted of 24 (15 female) 14-month-olds (M = 14.07 months, SD = .18 months, range = 13.80 – 14.50 months). Participants were recruited in the same manner as Experiment 1. Infants were primarily identified as Caucasian (75%, n = 18) and multiracial (21%, n = 5). About 13% (n = 3) of infants were identified as Hispanic or Latino. An additional four infants were tested but excluded from final analyses for the following reasons: failure to meet the habituation criteria (n = 2), failure to finish the study due to fussiness (n = 1), and fussiness or inattentiveness during the study (n = 1).

Parental report confirmed that none of these infants were using emotion labels. No infants were reported to have produced the following words: "happy," "sad," "angry," "scared," or "disgusted" (or synonyms). Thus, infants in this sample did not have emotion labels in their expressive vocabularies.

3.5.1.2 Stimuli

The stimuli were identical to Experiment 3. However, a verbal label (i.e., "toma") was added to each of the six habituation events in the same manner as Experiment 2. This label was only presented with the habituation trials: the test trials were presented in silence, without labels.

3.5.1.3 Apparatus and Procedure

All infants were tested in the *Disgust-Sad* condition. All other aspects of the apparatus and procedure were identical to Experiment 2.

3.5.1.4 Scoring

The scoring procedure was identical to Experiment 2. Reliability was excellent (50% of tapes rescored; $n = 12$) for duration of looking on each trial, $r = .96$, $p < .001$.

3.5.2 *Results*

3.5.2.1 Habituation Phase

A paired samples t-test confirmed that infants' looking behavior significantly decreased from habituation to test, $t(23) = 7.15$, $p < .001$, $d = 2.11$. Infants had significantly higher looking times during the first three habituation trials ($M = 24.33$s, $SD = 5.43$s) compared to the *negative familiar event* ($M = 11.03$s, $SD = 7.07$s).

3.5.2.2 Test Phase

Infants' looking times during the test trials were analyzed in a repeated-measures ANOVA. This analysis yielded a significant main effect of Test Trial, $F(3, 69) = 5.81$, $p = .001$, $\eta_p^2 = .20$. Follow-up paired t-tests revealed that infants looked significantly longer at the *positive novel emotion* compared to the *negative familiar event* ($p < .001$, $d = .96$), the *negative novel face* ($p < .001$, $d = .92$), and the *negative novel emotion* ($p < .001$, $d = 1.05$). Critically, however, infants' looking to the *negative familiar event* did not differ from the *negative novel face* ($p > .25$, $d = .01$) or the *negative novel emotion* ($p > .25$, $d = .07$), and looking to the *negative novel face* did not differ from the *negative novel emotion* ($p > .25$, $d = .05$). Thus, infants formed a superordinate category of negative valence (see Table 3.1 for cell means).

3.5.2.3 Combined Experiment 3 and Experiment 4 Analysis

To confirm that the addition of a label impacted infants' categorization, data from Experiments 3 and 4 were analyzed in a 4 (Test Trial) x 2 (Experiment) mixed-model ANOVA. As expected, a significant main effect of Test Trial, $F(3, 138) = 4.36$, $p = .006$, $\eta_p^2 = .09$, was qualified by a Test Trial x Experiment interaction, $F(3, 138) = 3.29$, $p = .023$, $\eta_p^2 = .07$. Therefore, infants' looking time during the test trials significantly differed between the two experiments (Figure 3.4). There was no significant main effect of Experiment, $F(1, 46) = 3.55$, $p = .07$, $\eta_p^2 = .07$.

3.6 General Discussion

This series of experiments are the first to demonstrate that (a) in the second year of life, infants do not spontaneously form superordinate categories of negative emotional expressions and (b) novel verbal labels can help infants form these categories. Specifically, in Experiments 1 and 3, infants did not form a superordinate category of negative valence for facial expressions of disgust, anger, and sadness displayed by multiple people. However, when a novel label ("toma") was added to each habituation trial in Experiments 2 and 4, infants were able to form this category. These labeling effects were obtained using emotional expressions from two different stimuli sets and even when controlling for the amount of teeth displayed on the expressions.

It is noteworthy that infants in the *Disgust-Sad* condition were able to form a superordinate category of negative valence when a verbal label was provided. The addition of a label may have prompted infants to search for (and find) the commonalities between the emotional expressions (Waxman & Markow, 1995). The label may have shifted infants' focus away from the variable features of the stimuli (Althaus & Plunkett, 2016), such as the scrunched noses on the disgust faces and downturned mouths on the sad faces. In turn, the label may have

drawn infants' attention towards the shared, abstract feature of the stimuli: their negative valence. Thus, the addition of a label enabled infants to form a category that included, (a) a familiarized person expressing disgust or sadness (*negative familiar event*), (b) a new person expressing disgust or sadness (*negative novel face*), and (c) a familiarized person expressing anger (*negative novel emotion*). Infants also attended significantly less to these three *negative* test trials compared to the *positive novel emotion*. Thus, labels prompted infants to form a superordinate category of negative valence that differed from a novel happy expression.

Although the provision of labels in the *Disgust-Sad* condition enabled infants to form a superordinate category that included anger, sad, and disgust expressions, infants did not form this category when habituated to anger and sad expressions (*Anger-Sad* condition). Habituation condition differences are common in emotion categorization studies (e.g., Kotsoni et al., 2001; Ruba et al., 2017), and there are several possible explanations for these findings. First, labels do not facilitate category formation if objects do not belong to an obvious category (Waxman & Markow, 1995). Thus, one possibility is that, during the habituation trials, infants viewed the anger and sad expressions as belonging to separate, unrelated categories. Given that the anger and sad expressions did not show teeth in Experiments 1 and 2, infants could not have based their categories on this perceptual feature. Instead, emotional arousal may have been the basis for forming these categories. Similar to valence, emotional arousal (or "activation") is another dimension on which emotions can be categorized (Russell, 1980). In the current study, anger is "high" arousal, while sadness is "low" arousal (Widen & Russell, 2008). On the other hand, in the *Disgust-Sad* condition, it may have been easier for infants to form a superordinate category since the two habituation emotions (i.e., disgust and sadness) are closer in arousal level ("moderate" vs. "low" arousal; (Croucher, Calder, Ramponi, Barnard, & Murphy, 2011; Widen

& Russell, 2008). Furthermore, anger, disgust, and sadness also differ with respect to their behavioral signal: while anger expressions signal behavioral approach, disgust and sad expressions do not (Shariff & Tracy, 2011). This behavioral signal could have been another dimension that infants used to differentiate the anger and sad expressions.

The pattern of results obtained across these four studies counter predictions made by the "theory of constructed emotion" (Barrett, 2017). Specifically, this theory predicts that (a) preverbal infants (exclusively) form superordinate categories of emotional expressions, and (b) labels facilitate the *division* of these superordinate categories into basic-level categories (e.g., anger, disgust). The current studies found that infants *did not* spontaneously form superordinate categories of negative valence, but labels facilitated the *formation* of these categories. Thus, these findings are more in line with predictions made by Quinn et al. (2011), who hypothesize that infants differentiate emotional expressions in a "narrow-to-broad" pattern. In other words, infants may initially form basic-level categories of different negative emotional expressions (e.g., anger vs. disgust) before appreciating that these facial expressions also belong to a superordinate category of "negative valence." Interestingly, infant object categorization seems to follow a "broad-to-narrow" pattern, whereby infants form superordinate categories (e.g., mammals) earlier in development than basic-level categories (e.g., cats; Mandler & McDonough, 1993; Quinn & Johnson, 2000). Therefore, while labels facilitate superordinate categorization for both emotional expressions and objects (e.g., Waxman & Markow, 1995), emotion category development may follow a different developmental trajectory than object category development.

The current studies are only a first step to documenting the influence of language on infants' emotion category formation. Importantly, it is unclear whether infants in these studies formed a category of negative valence that was distinct from a category of "positive valence."

Since only one positive emotional expression (i.e., happiness) was included in the test trials, it is possible that infants were responding to specific features of the happy expression, rather than to a category of positive valence per se. The current findings also cannot speak to the mechanism by which labels facilitated categorization. For example, future research is needed to determine whether and how labels impacted the visual processing of the emotional expressions (Althaus & Plunkett, 2016). Finally, more research is needed to confirm whether emotion categorization follows a "narrow-to-broad" pattern of differentiation, distinct from the "broad-to-narrow" pattern of object categorization. Studies with additional ages and emotional expressions may determine (a) whether there are any circumstances in which infants will form a superordinate category of negative valence without labels, and (b) if so, whether labels can facilitate the division of this superordinate category. With these additional studies, researchers can more fully understand how infants' emotion categories emerge and change over the course of development.

3.7 **Supplementary Analyses**

3.7.1 *Experiment 1 Additional Analyses*

3.7.1.1 Age Analyses

Although the Age x Test Trial interaction was not significant, separate 4 (Test Trial) x 2 (Condition) mixed-model ANOVAs were conducted for each age group to confirm that both groups failed to form a superordinate category (see Figure 3.5). A significant effect of Test Trial was found for the 14-month-olds, $F(3, 138) = 13.65$, $p < .001$, $\eta_p^2 = .23$. Fourteen-month-olds attended significantly less to the *negative familiar event* compared to the *negative novel face* ($p < .001$, $d = .80$), the *negative novel emotion* ($p < .001$, $d = .86$), and the *positive novel emotion* ($p < .001$, $d = 1.30$). Infants at this age also looked significantly longer at the *positive novel emotion* compared to the *negative novel face* ($p = .022$, $d = .46$) and marginally longer to the *negative*

novel emotion ($p = .067$, $d = .34$). A significant effect of Test Trial was also found for the 18-month-olds, $F(3, 138) = 18.50$, $p < .001$, $\eta_p^2 = .29$. Eighteen-month-olds attended significantly less to the *negative familiar event* compared to the *negative novel face* ($p < .001$, $d = 1.11$), the *negative novel emotion* ($p < .001$, $d = .99$), and the *positive novel emotion* ($p < .001$, $d = 1.37$). There were no other significant comparisons for either age (see Table 3.2 for cell means).

3.7.1.2 Did 14-month-olds Track the Habituation Events in the Disgust-Sad Condition?

A repeated measures ANOVA confirmed a significant effect of Test Trial for the 14-month-olds in the *Disgust-Sad* condition, $F(3, 69) = 31.66$, $p < .001$, $\eta_p^2 = .25$. Much like the overall sample, these infants attended significantly less to the *negative familiar event* compared to the *negative novel face* ($p = .003$, $d = .87$), the *negative novel emotion* ($p = .013$, $d = .71$), and the *positive novel emotion* ($p < .001$, $d = 1.23$). This suggests that the 14-month-olds in the *Disgust-Sad* condition were able to track which event they had seen during habituation, despite being unable to form a superordinate category (see Table 3.2 for cell means).

3.7.2 *Experiment 2 Additional Analyses*

3.7.2.1 Age Analyses

Although the Age x Trial x Condition interaction was not significant, separate repeated-measures ANOVAs were conducted for each age group to confirm that both groups formed a superordinate category in the *Disgust-Sad* condition (see Table 3.2 and Figure 3.6). A significant effect of Test Trial emerged for the 14-month-olds, $F(3, 93) = 14.42$, $p < .001$, $\eta_p^2 = .31$, and the 18-month-olds, $F(3, 93) = 5.00$, $p = .003$, $\eta_p^2 = .14$. Similar to the overall sample, paired t-tests revealed that 14-month-olds looked significantly longer at the *positive novel emotion* compared to the *negative familiar event* ($p < .001$, $d = 1.26$), the *negative novel face* ($p < .001$, $d = 1.03$), and the *negative novel emotion* ($p < .001$, $d = 1.20$). Infants' looking to the *negative familiar*

event did not differ from the *negative novel face* ($p > .25$, $d = .17$) or the *negative novel emotion* ($p > .25$, $d = .04$) and looking to the *negative novel face* did not differ from the *negative novel emotion* ($p > .25$, $d = .19$). Similar results were found for the 18-month-olds. Paired t-tests revealed that 18-month-olds looked significantly longer at the *positive novel emotion* compared to the *negative familiar event* ($p = .002$, $d = .83$), the *negative novel face* ($p = .040$, $d = .47$), and the *negative novel emotion* ($p = .022$, $d = .52$). Infants' looking to the *negative familiar event* did not differ from the *negative novel face* ($p = .14$, $d = .34$) or the *negative novel emotion* ($p = .14$, $d = .32$), and looking to the *negative novel face* did not differ from the *negative novel emotion* ($p > .25$, $d = .03$).

3.7.2.2 Analyses to Equate the Sample Size of Experiment 1 with Experiment 2

In order to compare the results of Experiment 1 and 2 with the same sample size we also ran an analysis in which we used only the first 24 infants tested in each age/condition in Experiment 2, thereby equating the sample size with Experiment 1. The results were the same as when the full *N* was tested (as reported in the main text). For completeness, the analyses with the reduced *N* are provided below (see Table 3.2 for cell means).

Habituation Phase. A 2 (Age) x 2 (Condition) x 2 (Trials) mixed-model ANOVA was conducted. A significant main effect of Trials, $F(1, 92) = 405.70$, $p < .001$, $\eta_p^2 = .82$, revealed that infants looked significantly longer to the first three habituation trials ($M = 24.57$s, $SD = 4.83$s) compared to the *negative familiar event* ($M = 10.23$s, $SD = 6.59$s). There were no other significant effects. Thus, infants did not reach the habituation criteria by chance.

Test Phase. Infants' looking times during the test trials were analyzed in a 4 (Test Trial) x 2 (Age) x 2 (Condition) mixed-model ANOVA. Significant main effects of Test Trial, $F(3, 276) = 21.96$, $p < .001$, $\eta_p^2 = .19$, and Condition, $F(1, 92) = 7.78$, $p = .006$, $\eta_p^2 = .08$, were

qualified by a significant Test Trial x Condition interaction, $F(3, 276) = 6.13$, $p < .001$, $\eta_p^2 = .06$. There were no significant main effects or interactions.

Follow-up analyses were conducted separately by Condition. For the *Anger-Sad* condition, a significant main effect of Test Trial emerged, $F(3, 138) = 14.89$, $p < .001$, $\eta_p^2 = .24$. Follow-up comparisons revealed that infants looked significantly less at the *negative familiar event* compared to the *negative novel face* ($p < .001$, $d = .84$), the *negative novel emotion* ($p < .001$, $d = 1.01$), and the *positive novel emotion* ($p < .001$, $d = 1.07$). There were no other significant effects. Thus, as in Experiment 1, infants did not form a superordinate category of negative valence in the *Anger-Sad* condition.

For the *Disgust-Sad* condition, a significant main effect of Test Trial also emerged, $F(3, 138) = 13.08$, $p < .001$, $\eta_p^2 = .22$. Follow-up comparisons between the test trials revealed that infants looked significantly more at the *positive novel emotion* compared to the *negative familiar event* ($p < .001$, $d = 1.02$), the *negative novel face* ($p < .001$, $d = .89$), and the *negative novel emotion* ($p < .001$, $d = .80$). Critically, however, infants' looking to the *negative familiar event* did not differ from the *negative novel face* ($p > .25$, $d = .15$) or the *negative novel emotion* ($p > .25$, $d = .19$), and looking to the *negative novel face* did not differ from the *negative novel emotion* ($p > .25$, $d = .04$). Thus, infants formed a superordinate category of negative valence in the *Disgust-Sad* condition.

3.7.3 *Exploratory Vocabulary Analyses*

A secondary aim of Experiment 2 was to explore whether infants' vocabulary size was related to their looking times during the test trials. Preliminary analyses indicated that18-month-olds had significantly larger receptive vocabularies ($M = 199.05$, $SD = 92.11$), $t(118.23) = 6.60$, $p < .001$, $d = 1.17$, and expressive vocabularies ($M = 66.78$, $SD = 72.96$), $t(67.62) = 5.79$, $p <$

.001, d = 1.02, compared to 14-month-olds (receptive: M = 103.11, SD = 70.87; expressive: M = 13.00, SD = 13.98). For this reason, the vocabulary analyses were conducted separately by Age. Given the differences in category formation between the *Anger-Sad* and *Disgust-Sad* conditions, vocabulary analyses were also conducted separately by Condition. Three difference scores were calculated for infants, representing the difference between their looking time to each of the *novel* test trials relative to the *negative familiar event* test trial. Difference scores greater than zero indicate longer looking time to the novel test trials. Correlations were then calculated to examine whether receptive and/or expressive vocabulary scores were related to these difference scores.

In the receptive vocabulary analyses, one 14-month-old in the *Anger-Sad* condition was excluded due to an extremely high vocabulary score (+3 *SD* above the mean). For the 18-month-olds in the *Disgust-Sad* condition, receptive vocabulary was significantly and positively related to looking time to the *negative novel face*, r = .39, p = .026. There were no other significant correlations (see Table 3.3).

In the expressive vocabulary analyses, two 14- and two 18-month-olds (one infant in each condition) were excluded due to extremely high vocabulary scores (+3 *SD* above the mean). For the 14-month-olds in the *Anger-Sad* condition, expressive vocabulary was significantly and negatively related to looking time to the *negative novel face*, r = -.32, p = .032, and the *positive novel emotion*, r = -.37, p = .043. Expressive vocabulary was also marginally negatively related to looking time to the *negative novel emotion*, r = -.34, p = .064. There were no other significant correlations (see Table 3.3).

In summary, 14-month-olds with larger expressive vocabularies spent less time looking at the *novel* test events in the *Anger-Sad* condition. This finding is consistent with previous research in which it has been found that labels are more likely to facilitate categorization among

infants with larger vocabularies (e.g., Waxman & Markow, 1995). In contrast, 18-month-olds with smaller receptive vocabularies spent less time looking at the *negative novel face* event in the *Disgust-Sad* condition. In other words, labels were more likely to facilitate categorization among infants with smaller receptive vocabularies. This result was unexpected, and to the best of our knowledge, has not previously been found in the literature. However, given the relatively small sample sizes used to conduct these correlations (n = 32), this finding requires replication.

3.8 Tables and Figures

Table 3.1. Experiment 1-4 main analyses: Mean looking times (and standard deviations) in seconds during the test trials. Conditions are Anger-Sad (AS) and Disgust-Sad (DS).

Exp.	Condition	Age	*n*	Negative Familiar Event	Negative Novel Face	Negative Novel Emotion	Positive Novel Emotion
1	AS, DS	14, 18	96	7.00 (4.22)	13.07 (8.02)	13.40 (8.67)	16.21 (8.79)
2	AS	14, 18	64	10.99 (7.32)	17.17 (8.84)	18.36 (9.29)	18.70 (8.28)
2	DS	14, 18	64	10.72 (6.14)	12.47 (7.29)	11.69 (7.05)	18.10 (8.04)
2	AS, DS	14	64	10.42 (6.58)	13.26 (7.54)	14.09 (8.65)	19.37 (8.22)
2	AS, DS	18	64	11.30 (6.90)	16.37 (8.99)	15.96 (9.06)	17.44 (8.01)
3	DS	14	24	11.34 (7.01)	7.66 (4.90)	10.99 (8.87)	10.65 (8.50)
4	DS	14	24	11.03 (7.07)	10.95 (7.81)	10.56 (6.76)	17.65 (6.76)

Table 3.2. Experiment 1 and 2 supplementary analyses. Mean looking times (and SD) in seconds during the test trials. Conditions are Anger-Sad (AS) and Disgust-Sad (DS).

Exp.	Condition	Age	*n*	Negative Familiar Event	Negative Novel Face	Negative Novel Emotion	Positive Novel Emotion
1	AS, DS	14	48	6.54 (3.90)	11.42 (7.74)	12.26 (8.57)	15.16 (8.52)
1	AS, DS	18	48	7.46 (4.51)	14.71 (8.04)	14.55 (9.09)	17.25 (9.03)
1	DS	14	24	6.10 (2.80)	11.38 (8.12)	9.94 (7.16)	13.58 (8.12)
2	DS	14	32	10.68 (5.85)	11.77 (6.92)	10.45 (7.03)	19.18 (7.50)
2	DS	18	32	10.76 (6.51)	13.17 (7.69)	12.94 (6.96)	17.02 (8.53)
2	AS	14, 18	48	10.00 (6.75)	16.69 (6.31)	17.97 (8.79)	18.17 (8.37)
2	DS	14, 18	48	10.46 (6.48)	11.45 (6.31)	11.76 (7.11)	17.81 (7.91)

Table 3.3. Correlations between receptive and expressive vocabulary and emotion difference scores in Experiment 2, *$p < .05$, ^$p < .10$

	14-month-olds		18-month-olds	
	Receptive	Expressive	Receptive	Expressive
Anger-Sad				
Nov Neg Face	-.01	-.39*	-.17	-.06
Nov Neg Emo	.12	-.34^	-.26	-.17
Nov Pos Emo	.19	-.37*	-.10	-.08
Disgust-Sad				
Nov Neg Face	-.17	-.19	.39*	.23
Nov Neg Emo	-.07	-.04	.28	.10
Nov Pos Emo	-.21	-.26	.16	-.08

Figure 3.1. Experiment 1 and 2: Sample habituation and test events. Habituation and test events were presented in a randomized order.

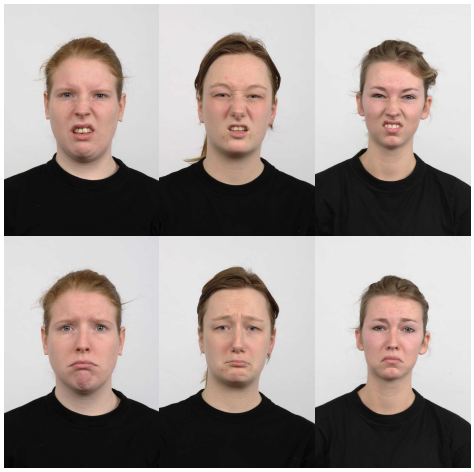
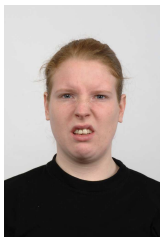
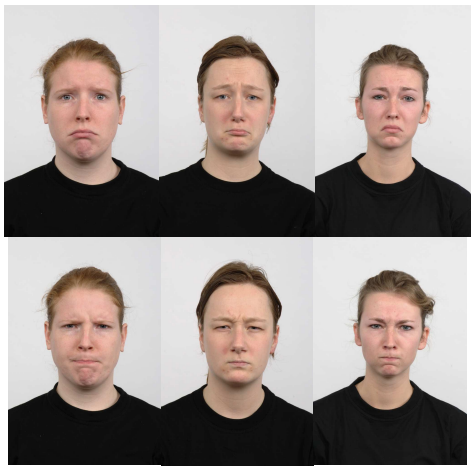
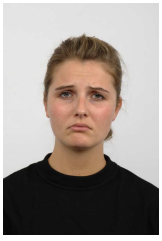
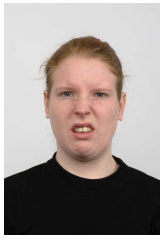
Disgust-Sad Habituation Stimuli	**Disgust-Sad Test Stimuli**			
	Negative Familiar Event (disgust)	Negative Novel Face (sadness)	Negative Novel Emotion (anger)	Positive Novel Emotion (happiness)
				
Anger-Sad Habituation Stimuli	**Anger-Sad Test Stimuli**			
	Negative Familiar Event (anger)	Negative Novel Face (sadness)	Negative Novel Emotion (disgust)	Positive Novel Emotion (happiness)
				

Figure 3.2. Experiment 2: Infants' mean total looking time (and *SE*) during the test trials, separated by Condition, *$p < .05$ for pairwise comparisons between events.

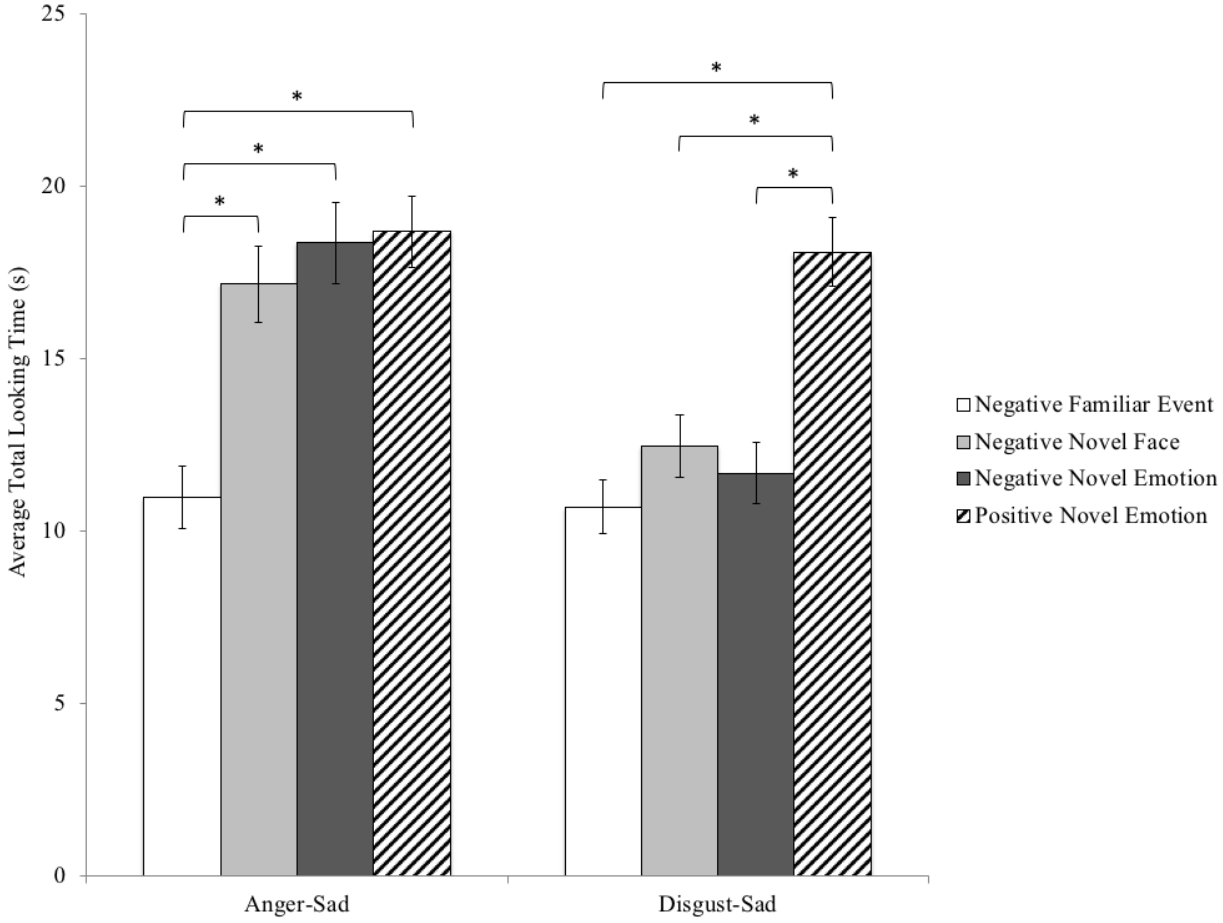


Figure 3.3. Experiment 3 and 4: Sample stimuli (*Disgust-Sad* condition only). Habituation and test events were presented in a randomized order.

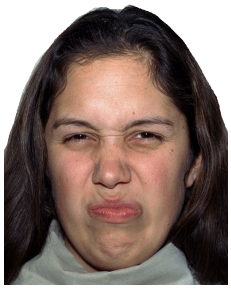
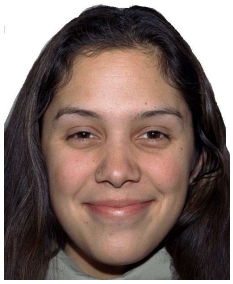
Disgust	Sadness	Anger	Happiness
			

Figure 3.4. Experiment 3 and 4: Infants' mean total looking time (and *SE*) during the test trials, separated by Experiment, *$p < .05$ for pairwise comparisons between events.

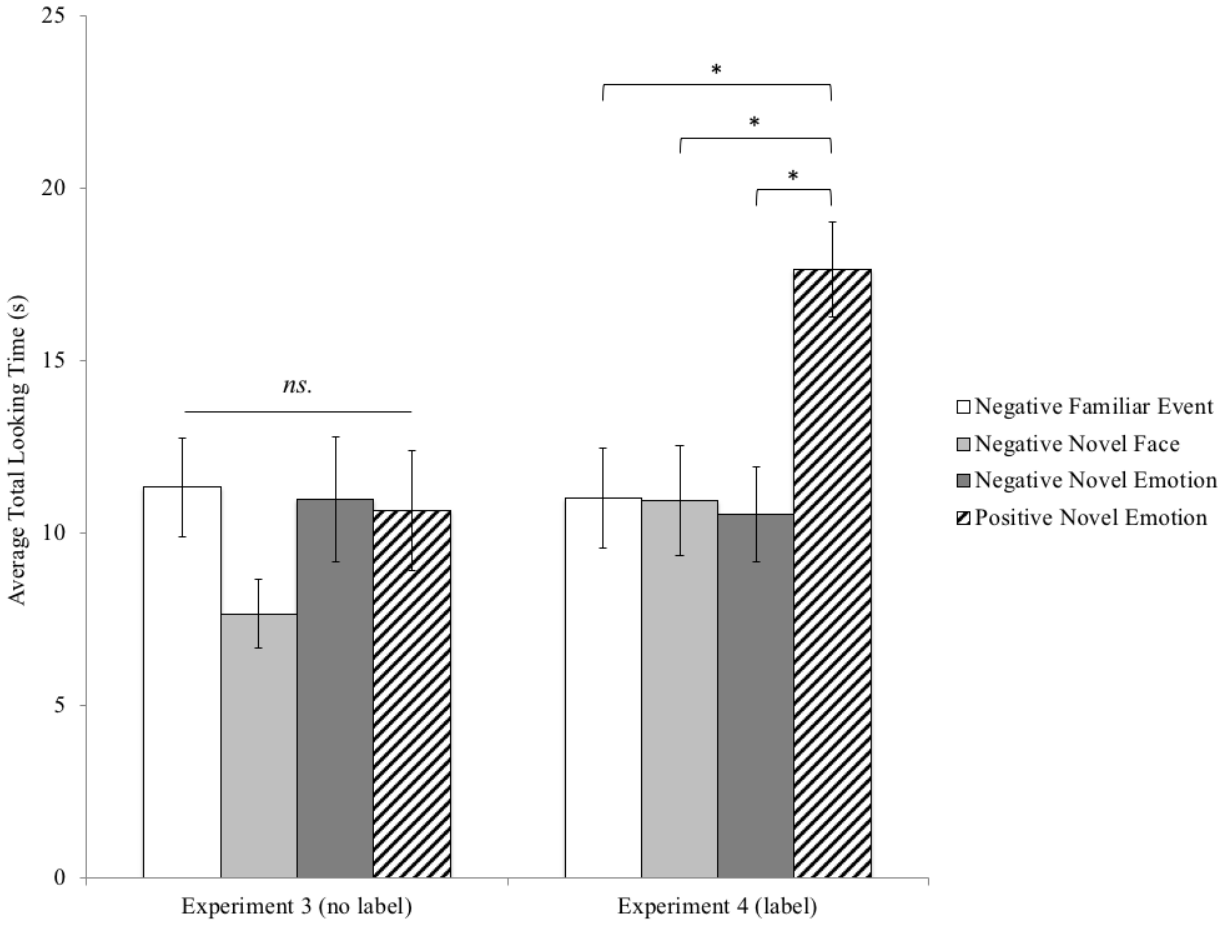


Figure 3.5. Experiment 1 supplementary analyses: Infants' mean total looking time (and *SE*) during the test trials, **p* < .05, +*p* < .10, for pairwise comparisons between events.

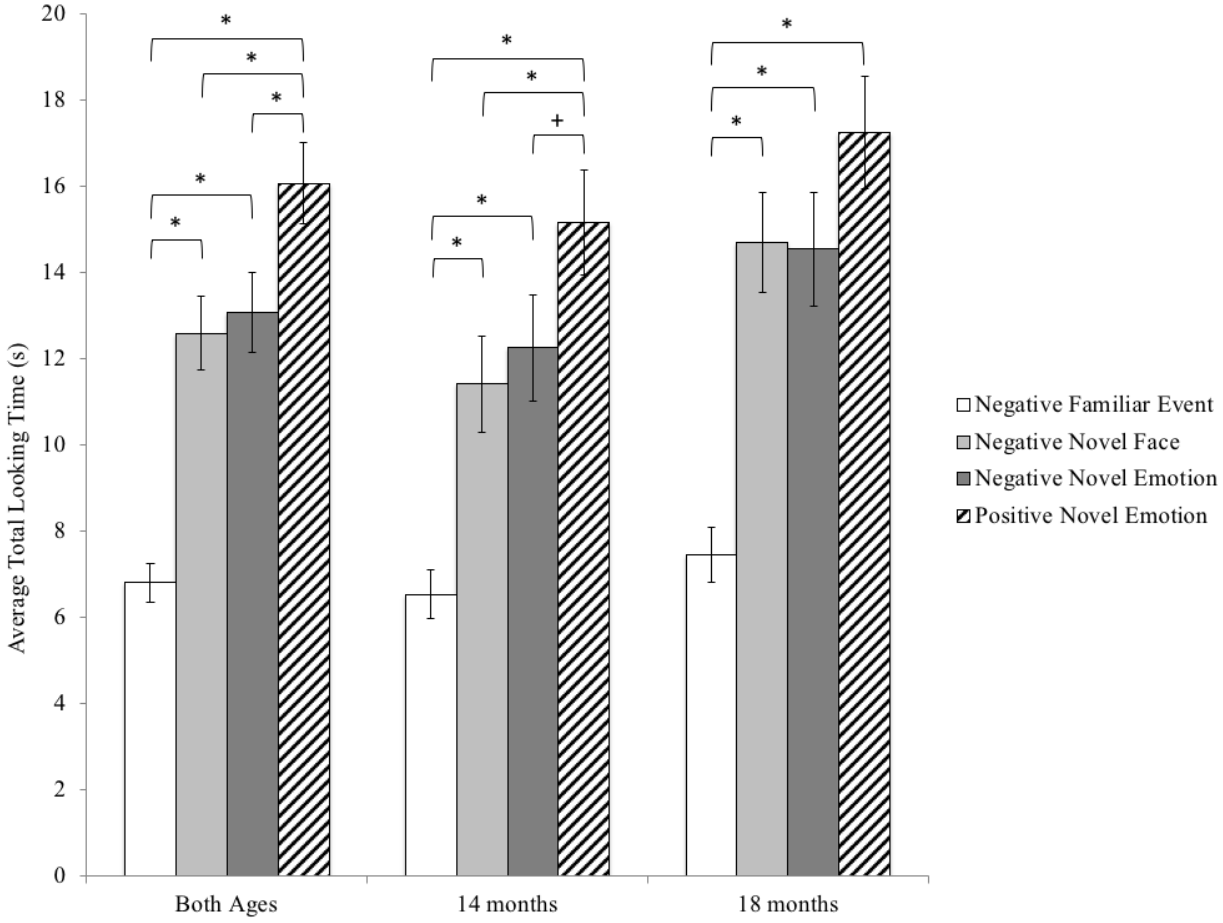
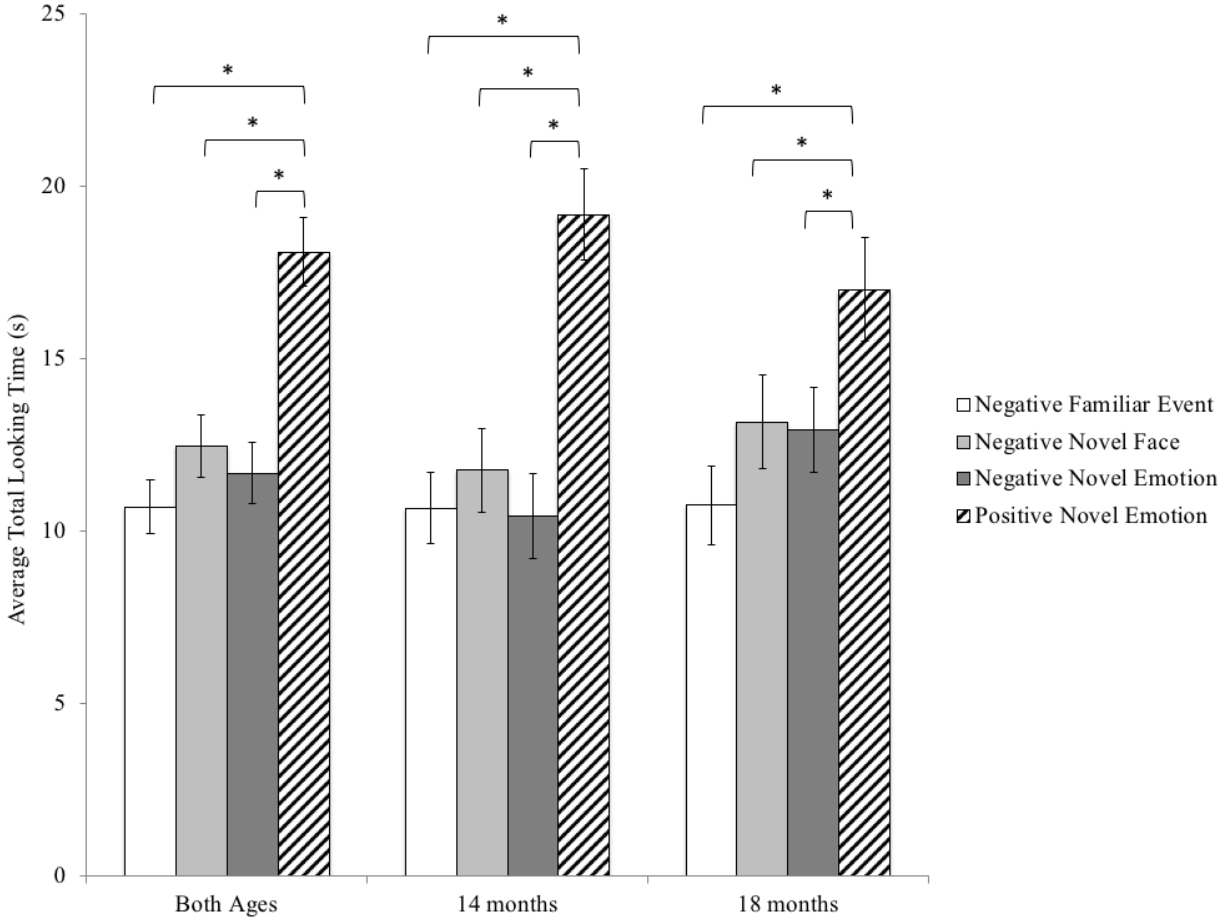


Figure 3.6. Experiment 2 supplementary analyses: Infants' mean total looking time (and *SE*) during the test trials, *$p < .05$, for pairwise comparisons between events.



Chapter 4. DEVELOPMENTAL PROGRESSION OF EVENT-EMOTION MATCHING

4.1 Introduction

Humans experience and express a wide variety of emotions. Emotions are often expressed in response to eliciting events, and adults have common knowledge about these event-emotion pairings (Lewis, 2016). For example, adults might expect that tasting spoiled food or receiving a desired gift would elicit a disgusted or happy expression, respectively. At the same time, it is more unexpected that these events would elicit other emotional expressions, such as sadness or fear. The ability to match emotions to events is an important component of "emotion understanding" (Denham, 1986; Denham, Zoller, & Couchoud, 1994) and is related to greater academic competence, more positive peer relationships, and fewer social problems (e.g., Fine, Izard, & Trentacosta, 2006; Garner, Jones, & Miner, 1994; Schultz, Izard, Ackerman, & Youngstrom, 2001; Trentacosta & Izard, 2007). For this reason, there has been recent interest in studying the developmental origins of event-emotion matching in infancy. This emerging literature suggests that, from 12-months of age, infants are able to match different emotional expressions to specific eliciting events (Chiarella & Poulin-Dubois, 2013; Reschke et al., 2017; Ruba et al., 2019; Wu et al., 2017). However, much less is known about how this ability emerges and changes in the first year of life (Hepach & Westermann, 2013; Skerry & Spelke, 2014). The current studies examine (a) how 10-month-olds match emotional expressions to eliciting events, and (b) potential developmental changes in event-emotion matching between 10- and 14-months of age.

4.1.1 *The Development of Emotion Understanding in the First Year of Life*

In general, emotions can be understood as "concepts" (Barrett, 2017). An emotion concept is a group of expressive behaviors, eliciting events, behavioral consequences, and labels

that are related to a specific emotion (Fehr & Russell, 1984; Widen & Russell, 2011). For example, receiving a desired gift may elicit a wide smile, which is labeled as "happiness." The ability to match emotional expressions to eliciting events is one component of "understanding" an emotion concept, and there is considerable disagreement as to how these emotion concepts are acquired. On the one hand, classical emotion theories suggest that specific emotion concepts for certain "basic" emotions (i.e., happiness, sadness, anger, fear, and disgust; Ekman, 1994) are either innately understood or easily acquired in infancy (e.g., Izard, 1994). On the other hand, constructionist theories have argued that preverbal infants have broad, valence-based emotion concepts (i.e., positive vs. negative) that gradually narrow into more specific concepts (e.g., anger vs. disgust) over the first decade of life (Widen, 2013; Widen & Russell, 2008). This narrowing is thought to occur alongside the acquisition of emotion labels (e.g., "happy") around age 2 (Barrett, 2017; Barrett, Lindquist, & Gendron, 2007; Lindquist & Gendron, 2013). To date, it is unclear which theory best accounts for emotion concept understanding in infancy, as studies with infants have generally not been designed to test whether infants "understand" specific emotional expressions.

4.1.2 *Discrimination and Categorization*

Instead, studies with infants in the first year of life have largely focused on emotion *discrimination and categorization*. Emotion discrimination is the ability to perceive the difference between two facial expressions (e.g., happiness vs. fear) displayed by the same person (Walker-Andrews, 1997). Emotion categorization is the ability to group different instances of a facial expression (i.e., multiple people smiling) together as members of the same category (e.g., "happiness"; Ruba et al. 2017). Together, these studies suggest that, by 5-months of age, infants are able to discriminate between positive and negative facial expressions (e.g., happy vs. fear;

Bornstein & Arterberry, 2003; Flom & Bahrick, 2007; Geangu et al., 2016; Krol, Monakhov et al., 2015; Nelson et al., 2006). Around 7-months of age, infants are also able to form categories of positive facial expressions (e.g., happiness) and differentiate this category from negative facial expressions (e.g., anger, fear; Kestenbaum & Nelson, 1990; Ludemann, 1991; Safar & Moulson, 2017). Far fewer studies have examined whether infants can discriminate between and form categories of different negative facial expressions (e.g., anger vs. fear). However, it appears that infants in the first year of life may also be able to make these distinctions (e.g., Ruba et al., 2017; Schwartz et al, 1985; Soken & Pick, 1999; White et al., 2019; Xie et al., 2019).

Although infants at this age can discriminate and categorize a variety of emotional facial expressions, unfortunately, these findings cannot speak to how infants "understand" these emotions. Currently, there is no empirical test to determine the nature of infants' responses in these tasks (Madole & Oakes, 1999). For this reason, it is possible that infants discriminate and categorize facial expressions based on salient facial features (e.g., amount of teeth shown), rather than on affective meaning (Barrett, 2017; R. F. Caron et al., 1985).

4.1.3 *Social Referencing*

Comparatively, social referencing studies provide a clearer test of infants' ability to "understand" emotional expressions. In social referencing studies, infants use another' person's emotional expression to regulate their own behavior (Klinnert et al., 1986; Sorce et al., 1985; Walden & Ogan, 1988). Most social referencing studies test infants in the second year of life (i.e., 12-months and older). Overall, these studies have found that infants tend to (a) approach and/or touch an object if an Emoter displays a positive emotional expression (e.g., happiness), and (b) avoid an object if an Emoter displays a negative emotional expression (e.g., fear, disgust; Carver & Vaccaro, 2007; Chiarella & Poulin-Dubois, 2018; Kim & Kwak, 2011; Vaish et al.,

2008). Thus, it appears that infants at this age appreciate that negative emotional expressions warn of a possible threat, while positive emotional expressions communicate a lack of threat (Shariff & Tracy, 2011). However, the few studies of younger infants have failed to find evidence of this differential behavioral responding in younger, 6- to 9-month-olds (Mumme & Fernald, 2003; Slaughter & McConnell, 2003; Walden & Baxter, 1989; Walden & Ogan, 1988). In other words, infants in the first year of life do not seem to respond to emotional expressions based on valence. Taken together with the discrimination and categorization literature, these findings suggest that infants in the first year of life are able to detect perceptual differences between facial expressions, but may not yet "understand" the affective meaning behind these expressions.

An alternative possibility is that these young infants *do have* valence-based emotion concepts, but are simply unable to use this knowledge to regulate their own object-directed behavior (e.g., they do not have sufficient inhibitory control). Several ERP (event-related potential) studies provide evidence for this possibility. For example, infants as young as 3-months, show increased Nc (negative central) activity to pictures of objects that were previously paired with fear or disgust expressions, compared to neutral or happy expressions (Carver & Vaccaro, 2007; Hoehl & Striano, 2010; Hoehl et al., 2008; but see, Aktar et al., 2016; Leventon & Bauer, 2013). Given that the Nc is thought to relate to increased allocation of attention (de Haan et al., 2003), these findings suggest that infants are more attentive to objects that were linked to negative facial expressions, perhaps because infants appreciate the "threat-signaling" value of these expressions (Vaish et al., 2008). In addition, Vaillant-Molina and Bahrick (2012) found evidence of differential behavioral responding to positive and negative emotional expressions with 5.5-month-olds. Specifically, infants preferentially touched a toy that had been

linked with a happy expression compared to a fearful expression. In this study, infants may have better encoded the emotion-object pairings because they were habituated to the pairings before the behavioral response period. In summary, infants in the first year of life may show evidence of valence-based emotion understanding when the tasks are less motorically and cognitively demanding.

4.1.4 *Event-Emotion Matching*

With this in mind, a recent body of research has turned to looking-time studies as a novel test of infants' emotion concepts. Using a violation-of-expectation (VOE) paradigm (Baillargeon et al., 1985), these studies present infants with a video of an event (e.g., receiving a gift) followed by an Emoter expressing a congruent (e.g., happiness) or incongruent emotion (e.g., sadness). If infants have formed links between specific emotional expressions and eliciting events, they should look longer at an expression that is incongruent with that event (e.g., receiving a gift and sadness) compared to the congruent expression (e.g., happiness). To date, only two studies have examined whether infants in the first year of life have valence-based emotion concepts. However, both studies have failed to find evidence for valence-based emotion understanding at this age.

In one study, Skerry and Spelke (2014) familiarized 10-month-olds with an agent (a geometric circle) engaging in goal-directed behavior. The agent moved around and jumped over barriers that varied in size/location in order to reach an object (Experiment 3). Infants were then presented with test trials in which the agent either completed or failed to complete its goal (because a barrier fell between the agent and object). The agent responded with either positive affect (smiling, giggling, and bouncing) or negative affect (frowning, crying, and slowly rocking side-to-side). After viewing the completed goal test event, infants attended longer to the negative

than the positive emotion. However, after viewing the failed goal event, there were no differences in infants' looking time to the two emotions. One interpretation of these findings is that 10-month-olds have not yet learned the link between failed goals and negative affect. Another possibility, however, is that the failed goal event was ambiguous. Given that the agent had previously jumped over the barrier in the familiarization trials, infants may have believed that the agent was still capable of completing its goal. In other words, infants may have viewed this event as an incomplete goal and consequently did not expect the agent to express a negative emotion.

In another study, Hepach and Westermann (2013) explored whether 10-month-olds could link positive and negative emotions to eliciting events, using pupil dilation as the dependent variable. Infants initially saw a videotape of a human Emoter displaying either a happy or angry facial expression. The Emoter continued to display the emotion while engaging in either a positive action (i.e., patting a stuffed animal) or a negative action (i.e., hitting a stuffed animal). Infants showed greater pupil dilation when watching the angry Emoter complete the positive action compared to the negative action. However, there were no differences in pupil dilation when watching the happy Emoter complete the positive and negative actions. When older 14-month-olds were tested with the same events, infants exhibited greater pupil dilation when each emotion was incongruent with the event. The authors attributed these results to developmental changes between 10- and 14-months. However, they also suggested that 10-month-olds may have misinterpreted the negative hitting action as "playful" behavior with the toy. Therefore, this event may not have been clearly negative from the perspective of a young infant.

4.1.5 *Rationale for the Current Studies*

In all, both social referencing and event-emotion matching studies suggest that, prior to 12 months of age, infants may not have valence-based emotion concepts. However, methodological limitations in these studies preclude any definitive conclusions. The current studies provide a new examination of this question by testing how 10-month-old infants link emotional responses to eliciting events. Experiment 1 examined whether infants at this age could match positive and negative emotional expressions (i.e., happiness vs. anger) to positive and negative events. Experiments 2 and 3 further explored (a) whether 10-month-olds can also link different negative emotional expressions (i.e., anger vs. disgust) to specific negative events, and (b) potential developmental changes in this ability from 10- to 14-months of age. These experiments differ from previous research (Hepach & Westermann, 2013; Skerry & Spelke, 2014) by using: (a) both facial and vocal expressions, displayed by human Emoters, and (b) *inter*personal events, rather than *intra*personal events, which may be easier for infants to understand (Reschke et al., 2017; Walle & Campos, 2012).

4.2 **Experiment 1**

Experiment 1 examined whether 10-month-olds expect an Emoter to express a positive emotion (*Happy*) after a positive event (*Toy Given*) and a negative emotion (*Anger*) after a negative event (*Toy Taken*). These two emotions were selected because they differ in terms of valence but are both high arousal emotions (Russell, 1980). In the *Toy Given* event, the Emoter received a desired object from an Actor. In the *Toy Taken* event, an Actor took a desired object away from the Emoter. Prosocial "giving" and antisocial "taking" actions were chosen, since prior research suggests that infants in the first year of life respond differentially to these actions (Hamlin & Wynn, 2011; Hamlin, Wynn, Bloom, & Mahajan, 2011).

After each event, infants saw the Emoter produce either a congruent or an incongruent emotional expression. For example, after viewing the *Toy Taken* event, infants in the *Anger* condition saw a congruent emotional expression at test, while infants in the *Happy* condition saw an incongruent expression. Infants' looking time to the emotional expression was recorded for each event, with the assumption that infants would attend longer to the incongruent emotional responses. Thus, we hypothesized that infants would attend significantly longer to: (a) the anger expression following the *Toy Given* event compared to the *Toy Taken* event, and (b) the happy expression following the *Toy Taken* event compared to the *Toy Given* event.

4.2.1 *Methods*

4.2.1.1 Participants

The final sample consisted of 60 (36 female) 10-month-old infants (M = 10.01 months, SD = .23, range = 9.57 – 10.45). The study was conducted following APA ethical standards and with approval of the Institutional Review Board (IRB) at the University of Washington (Approval Number: 50377, Protocol Title: "Emotion Categories Study"). Infants were recruited from a university database of parents who expressed interest in participating in research studies. All infants were healthy, full-term, and of normal birth weight. Parents primarily identified their infants as Caucasian (72%, n = 46) or multiracial (15%, n = 10). Approximately 8% of infants (n = 5) were identified as Hispanic or Latino. There was no attrition in this study.

4.2.1.2 Design

The design of the study was similar to Ruba et al. (2019). Equal numbers of male and female infants were randomly assigned to one of two emotion conditions: *Happy* or *Anger* (n = 30 per condition). Each infant watched two different videotaped events of an Emoter interacting with another person and an object (within-subjects): the *Toy Taken* event and the *Toy Given*

event. Infants were first presented with two familiarization trials of one of these events (e.g., *Toy Taken*). This was followed by a test trial in which the Emoter produced an emotional expression (e.g., anger in the *Anger* condition), and looking time was assessed. Following this test trial, infants were then presented with two familiarization trials of the other event (e.g., *Toy Given*), followed by a test trial of the same emotional expression (e.g., anger; **Figure 4.1**). The order in which the two events were presented was counterbalanced across participants.

4.2.1.3 Stimuli

Familiarization trials. The familiarization trials involved two videotaped events in which an adult male (the "Actor") and an adult female (the "Emoter") interacted with objects (described below). The Actor and Emoter were pleasantly neutral in both their facial and vocal expressions. Each event was approximately 20s in length (see **Figure 4.1**).

In the *Toy Given* event, the Actor played with a stuffed toy cow on the table, while the Emoter watched silently. The Emoter verbally requested the toy and the Actor complied by placing the toy in the Emoter's hands. The event ended with the Actor looking at the Emoter, who now had the toy in her hands. In the *Toy Taken* event, the Emoter played with the toy on the table, while the Actor watched silently. The Actor verbally requested the toy but the Emoter continued to play with it. Then, the Actor reached across the table and grabbed the toy out of the Emoter's hands. The event ended with the Emoter looking at the Actor, who now had the toy in his hands.

Test trials. The test trials were videotapes of the Emoter's emotional response to each event, which consisted of a facial expression and appropriate vocalization. The onset of the expression occurred after the Emoter was given the toy (*Toy Given*) or after the Actor took the toy away (*Toy Taken*). Facial expressions followed the criteria outlined by Ekman and Friesen

(1978). *Happiness* was expressed with a wide toothy smile, and *anger* was expressed with furrowed eyebrows and a tight mouth. During the expression, the Emoter maintained her gaze in the direction of the Actor. These test videos were cropped so that the Emoter was centered in the frame.

Vocal expressions consisted of "That's blicketing. That's so blicketing," spoken in either a happy or angry tone. Nonsense words were used to minimize infants' reliance on the lexical content of the vocalization. Thus, infants could only rely on the affective tone of the facial and vocal expressions to determine the conveyed emotion, rather than on the semantics of the nonsense words. After the Emoter finished her script (approximately 5s), she maintained her facial expression. The video was frozen at this point, to provide a still-frame of the Emoter's facial expression. This still-frame was shown for a maximum of 60s, during which infants' looking behavior was recorded (see Scoring). Full videos can be accessed here: https://osf.io/vsxm8/?view_only=2e149765de734f3bb7884369e01c9b9b. For validation information, see the Supplementary Analyses (page 146).

4.2.1.4 Apparatus

Each infant was tested in a small room, divided by an opaque curtain into two sections. In one half of the room, infants sat on their parent's lap approximately 60 cm away from a 48 cm color monitor with audio speakers. A camera was located approximately 10 cm above the monitor, focused on the infant's face to capture their looking behavior. In the other half of the room, behind the curtain, the experimenter operated a laptop computer connected to the test display monitor. A secondary monitor displayed a live feed of the camera focused on the infant's face, from which the experimenter observed infant's looking behavior. Habit 2 software (Oakes

et al., 2015) was used to present the stimuli, record infant's looking times, and calculate the looking time criteria (described below).

4.2.1.5 Procedure

Infants were seated on their parent's lap in the testing room. During the session, parents were instructed to look down and not speak to their infant or point to the screen. All parents complied with this request. Before each familiarization and test trial, an "attention-getter" (a blue flashing, chiming circle) attracted infants' attention to the monitor. The experimenter began each trial when the infant was looking at the monitor.

Infants were initially presented with two familiarization trials of one event (e.g., *Toy Given*). After these two event trials, infants were shown the Emoter's emotional expression, and infants' looking to the still frame of the Emoter's facial expression was recorded. For a look to be counted, infants had to look continuously for at least two seconds. The test trial played until infants looked away for more than two continuous seconds or until the 60s trial ended. Following this emotion test trial, infants were presented with two familiarization trials of the second event (e.g., *Toy Taken*), followed by a test trial of the same emotional expression (e.g., happiness; see **Figure 4.1**). The order in which the two events were presented was counterbalanced across participants.

4.2.1.6 Scoring

Infants' looking behavior was live-coded by a trained research assistant. For each event, this coding began at the end of the Emoter's vocal expression. Because the online coder was aware of the emotion the infant was currently viewing, a second trained research assistant recoded 100% of the videotapes offline, without sound. The coder was kept fully blind as to the participant's experimental condition and which emotion was presented to the infant. Agreement

between the live and naïve coder was excellent, $r = .99$, $p < .001$. Identical results were obtained using the online and offline coding (analyses with the offline reliability coding are reported below).

4.2.1.7 Hypothesis and Analysis Plan

Between-subjects analyses were planned separately for each event. If infants are able to form the predicted event-emotion matches, they should attend longer at the expression when it is incongruent with the event. Thus, after viewing the *Toy Taken* event, infants should attend longer to the *Happy* expression relative to the *Anger* expression. On the other hand, after viewing the *Toy Given* event, infants should attend longer to the *Anger* expression relative to the *Happy* expression.

4.2.2 *Results*

All infants, across both conditions, attended to the entirety of the familiarization trials. A 2 (Emotion: happy / anger) x 2 (Order: Toy Taken first / Toy Given first) analysis of variance (ANOVA) was conducted separately for each event.

4.2.2.1 Toy Taken Event

There was a significant main effect of Emotion, $F(1, 56) = 5.42$, $p = .024$, $\eta_p^2 = .09$. As expected, infants attended significantly longer to the *Happy* expression ($M = 33.52$ s, $SD = 15.59$) than the *Anger* expression ($M = 24.88$ s, $SD = 12.70$). There were no other significant main effects or interactions: Order, $F(1, 56) = .41$, $p > .25$, $\eta_p^2 = .01$; Order x Emotion, $F(1, 56) = .38$, $p > .25$, $\eta_p^2 = .01$.

4.2.2.2 Toy Given Event

Contrary to our predictions, there was not a significant main effect of Emotion, $F(1, 56) = .08$, $p > .25$, $\eta_p^2 < .01$. Infants did not attend significantly longer to the *Anger* expression ($M =$

27.61 s, *SD* = 15.34) compared to the *Happy* expression (*M* = 26.57 s, *SD* = 15.13). There was a significant main effect of Order, $F(1, 56) = 6.07$, $p = .017$, $\eta_p^2 = .10$, whereby infants attended significantly longer to Toy Given event when it was presented first (*M* = 31.72 s, *SD* = 14.28) compared to when it was presented second (*M* = 22.46 s, *SD* = 14.72). There was not a significant Order x Emotion interaction, $F(1, 56) = 1.52$, $p = .22$, $\eta_p^2 = .03$.

4.2.3 *Discussion*

These findings are the first to suggest that infants in the first year of life can match negative emotions to negative events. Specifically, 10-month-olds expected the Emoter would express anger, rather than happiness, after losing a desired toy. Previous studies had failed to find this effect with infants at this age (Hepach & Westermann, 2013; Skerry & Spelke, 2014). However, in the current study, we used a negative event that may have been less ambiguous and easier for infants to understand. In particular, we chose a negative "taking" event because (a) infants have self-experience with taking actions, and (b) infants at this age differentiate between "taking" and "giving" actions (Hamlin & Wynn, 2011; Hamlin et al., 2011). In addition, our event was *inter*personal, as opposed to *intra*personal. The social nature of emotion may make it easier for infants to understand emotions in these contexts (Reschke et al., 2017; Walle & Campos, 2012). Finally, it is also possible that the emotional displays themselves were easier for infants to understand. In the current study, the Emoter was human (rather than a geometric shape; Skerry & Spelke, 2014) and her emotion was expressed multi-modally (via face and voice). Consequently, these expressions may have provided 10-month-olds with a richer set of cues to correctly interpret the Emoter's affect.

Unexpectedly, and in contrast to previous research (Hepach & Westermann, 2013; Skerry & Spelke, 2014), infants in the first year of life *did not* match a positive emotion to a positive

event. Specifically, 10-month-olds did not expect the Emoter to express happiness, rather than anger, after receiving a desired toy. One possible explanation is that the *Toy Given* event was more difficult to understand than the *Toy Taken* event. For instance, when the Emoter requested the toy, she did so verbally (i.e., "Can I have the cow?"), and, as a result, 10-month-olds may not have understood that the Emoter *desired* the toy. When viewed in this way, anger could be an appropriate reaction to receiving a (potentially undesired) object from another person. Prior work also supports this interpretation. For example, although 18-month-olds expect a person to express happiness, rather than sadness, after receiving a desired object, younger, 15-month-olds do not seem to have these expectations (Chiarella & Poulin-Dubois, 2013). In addition, 12.5-month-olds do not expect an Agent to choose the same toy that they previously received from another person (Eason, Doctor, Chang, Kushnir, & Sommerville, 2018). These studies suggest that young infants do not view receiving actions as a strong indicator of a person's future object-directed behavior or emotional states.

4.2.3.1 Valence-Based Emotion Concepts?

Returning to the debate on infants' emotion understanding, our findings provide some evidence that infants may have emotion concepts based on positive and negative valence (Barrett, 2017; Barrett et al., 2007; Lindquist & Gendron, 2013). However, this first study is unable to address whether infants at this age may have more specific emotion concepts (e.g., anger vs. disgust). As with virtually all studies on infants' emotion understanding (for reviews, see Vaish et al., 2008; Walle & Campos, 2012), we only compared one positive emotion to one negative emotion. Therefore, it is impossible to determine whether infants' responses in this study reflected valence-based emotion understanding (i.e., positive vs. negative) or an understanding of specific emotions (i.e., happiness vs. anger). To this address question, infants'

responses to emotions *within* a dimension of emotional valence and arousal would need to be compared. If infants have some understanding of different emotions, above and beyond valence, then infants should expect a *specific* high arousal, negative emotional expression (e.g., disgust) to be associated with a *particular* negative event (e.g., tasting unpleasant food) compared to another high arousal, negative emotional expression (e.g., anger).

Although it is unclear whether infants in the first year of life understand different negative emotional expressions, studies suggest that 12- to 24-month-olds may have started to acquire this knowledge. For example, using a VOE paradigm, Ruba et al. (2019) found that 14- and 18-month-olds expected an Emoter to express (a) disgust, rather than anger or fear, after tasting a novel food, and (b) anger, rather than disgust or fear, after failing to complete a goal. In other words, infants were able to form some matches between specific negative emotions and different eliciting-events. In another looking-time study, Wu et al. (2017) demonstrated that 12- to 23-month-olds are able to match different positive, within-valence emotional vocalizations (e.g., "sympathy," "excitement") to specific events (e.g., a crying infant, a light-up toy). Finally, in a social referencing paradigm, Walle and colleagues (2017) found that 24-month-olds showed greater avoidance of an Emoter when she displayed anger, compared to sadness, disgust, and fear. In addition, 19-month-olds (but not 16- or 24-month-olds) demonstrated more "information seeking" (e.g., alternating their gaze between the object and Emoter) in response to disgust compared to anger. Taken together, these studies suggest that infants in the second year of life may not be limited to valence-based distinctions between emotional expressions. Thus, a secondary goal of Experiment 2 was to replicate these effects in a sample of 14-month-olds.

4.3 **Experiment 2**

Experiment 2 examined whether 10- and 14-month-olds expected an Emoter to express anger after an anger-congruent event (*Toy Taken*) and disgust after a disgust-congruent event (*New Food*). These two emotions were selected because they are both high arousal, negative emotions (Russell, 1980). In the *New Food* event, an Actor fed the Emoter a bite of food. The *Toy Taken* event was similar to Experiment 1. After each event, infants saw the Emoter produce either a congruent or an incongruent emotional expression. For example, after viewing the *New Food* event, infants in the *Disgust* condition saw a congruent emotional expression, while infants in the *Anger* condition saw an incongruent expression. If infants are able to match specific negative emotions to different events, then they should attend significantly longer to: (a) disgust, compared to anger, following the *Toy Taken* event, and (b) anger, compared to disgust, following the *New Food* event. Consistent with prior research (Ruba et al., 2019), we predicted that 14-month-olds would be able to form these specific event-emotion matches. However, we did not expect that 10-month-olds would be able to form these matches.

4.3.1 *Methods*

4.3.1.1 Participants

The final sample consisted of 60 (32 female) 10-month-old infants (M = 10.06 months, SD = .20, range = 9.70 – 10.42) and 60 (40 female) 14-month-old infants (M = 14.06 months, SD = .22, range = 13.71 – 14.43). All infants were healthy, full-term, and of normal birth weight. Parents primarily identified their infants as Caucasian (77%, n = 96), multiracial (19%, n = 23). Approximately 5% of infants (n = 6) were identified as Hispanic or Latino. Participants were recruited in the same manner as Experiment 1. Five additional infants were tested but excluded

from the final sample for procedural error (n = 2, 1 10-month-old), failure to finish the study (n = 2, 1 10-month-old), and fussiness (n = 1 10-month-old).

4.3.1.2 Design

The design of the study was similar to Experiment 1. Equal numbers of male and female infants were randomly assigned to one of two emotion conditions: *Anger* or *Disgust* (n = 30 per condition). Each infant watched two different videotaped events of an Emoter interacting with another person and an object (within-subjects): the *Toy Taken* event and the *New Food* event.

4.3.1.3 Stimuli.

Familiarization trials. The familiarization trials involved two videotaped events of two female adults (an "Actor" and an "Emoter") interacting with objects. Each event was approximately 15 s in length (see **Figure 4.2**). In the *New Food* event, the Actor placed a spoon and bowl on the table, which contained some nondescript food. The Emoter inquired about the food, and the Actor used the spoon to feed the Emoter a bite of food. The event ended when the spoon was in the Emoter's mouth. The *Toy Taken* event was similar to Experiment 1 with two changes: (a) a novel object was used (i.e., a toy dog), and (b) the Actor reached out his arms when verbally requesting the toy (i.e., to further indicate that he desired the toy).

Test trials. The test trials were videotapes of the Emoter's emotional response to each event. The onset of the Emoter's emotional expression occurred after she was fed the food (*New Food*) or after the toy was taken away (*Toy Taken*). Facial expressions followed the criteria set by Ekman and Friesen (1978). *Anger* was expressed with furrowed eyebrows and a tight mouth, and *disgust* was expressed with a protruding tongue and scrunched nose. During the emotional expression, the Emoter maintained her gaze on the spoon (which was pulled away from her mouth) or the toy (which was in the Actor's hands).

Vocal expressions began with an emotional utterance (e.g., a guttural "ugh" for *anger*, "ewww" for *disgust*) followed by, "That's blicketing. That's so blicketing," spoken in an angry/disgusted tone. These test videos were cropped so that only the Emoter and the object (i.e., spoon/bowl, toy) were present in the frame. After the Emoter finished her script (approximately 5 s), she maintained her facial expression. The video was frozen at this point to create a still-frame of the Emoter's facial expression for a maximum of 60 s, and infants' looking behavior was recorded. Full videos can be accessed here: https://osf.io/vsxm8/?view_only=2e149765de734f3bb7884369e01c9b9b. For validation information, see the Supplementary Analyses (page 146).

4.3.1.4 Apparatus and Procedure

The apparatus and procedure were identical to Experiment 1, except that infants viewed the *Toy Taken* and *New Food* events.

4.3.1.5 Scoring

A second trained research assistant recoded 100% of the tapes offline, without sound. The coder was kept fully blind as to the participant's experimental condition and which emotion was presented to the infant. Agreement was excellent, $r = .99$, $p < .001$. Identical results are obtained using the online and offline coding (analyses with the offline reliability coding are reported below).

4.3.1.6 Hypothesis and Analysis Plan

Between-subjects analyses were planned separately for each event. If infants are able to form the predicted event-emotion matches, they should attend longer at the expression when it is incongruent with the event. Thus, after viewing the *Toy Taken* event, infants should attend longer to the *Disgust* expression relative to the *Anger* expression. On the other hand, after viewing the

New Food event, infants should attend longer to the *Anger* expression relative to the *Disgust* expression.

4.3.2 *Results*

All infants, across both conditions, attended to the entirety of the familiarization trials. A 2 (Age: 10-months / 14-months) x 2 (Emotion: anger / disgust) x 2 (Order: toy-taken first / new-food first) analysis of variance (ANOVA) was conducted separately for each event.

4.3.2.1 Toy Taken Event

A significant main effect of Emotion emerged, $F(1, 112) = 5.82$, $p = .017$, $\eta_p^2 = .05$. Consistent with our hypotheses, infants looked longer at the *Disgust* expression compared to the *Anger* expression (for cell means, see Table 4.1). There were no other significant main effects or interactions: Age, $F(1, 112) = 1.11$, $p > .25$, $\eta_p^2 = .01$; Order, $F(1, 112) = .09$, $p > .25$, $\eta_p^2 < .01$; Age x Emotion interaction, $F(1, 112) = .06$, $p > .25$, $\eta_p^2 < .01$; Order x Emotion, $F(1, 112) = .02$, $p > .25$, $\eta_p^2 < .01$; Order x Age, $F(1, 112) < .01$, $p > .25$, $\eta_p^2 < .01$; Order x Age x Emotion, $F(1, 112) = .66$, $p > .25$, $\eta_p^2 = .01$.

4.3.2.2 New Food Event

Significant main effects of Order, $F(1, 112) = 6.63$, $p = .011$, $\eta_p^2 = .06$, and Age, $F(1, 112) = 5.03$, $p = .027$, $\eta_p^2 = .04$, emerged. Overall, infants attended longer to the *New Food* event when it was presented first ($M = 30.40$ s, $SD = 17.17$) compared to when it was presented second ($M = 22.98$ s, $SD = 15.07$). In addition, 14-month-olds attended longer to the *New Food* event ($M = 29.92$s, $SD = 16.30$) compared to the 10-month-olds ($M = 23.46$s, $SD = 16.17$). These main effects were qualified by a significant Age x Order x Emotion interaction, $F(1, 112) = 4.21$, $p = .043$, $\eta_p^2 = .04$. There were no other significant main effects or interactions: Emotion, $F(1, 112) =$

.74, $p > .25$, $\eta_p^2 = .01$; Order x Age, $F(1, 112) = .05$, $p > .25$, $\eta_p^2 < .01$; Age x Emotion, $F(1, 112) = 1.00$, $p > .25$, $\eta_p^2 = .01$; Order x Emotion, $F(1, 112) = .26$, $p > .25$, $\eta_p^2 < .01$.

Follow-up analyses were conducted separately by Order. When the *New Food* event was presented first, there were no significant main effects or interactions: Age, $F(1, 56) = 1.72$, $p = .20$, $\eta_p^2 = .03$; Emotion, $F(1, 56) = .05$, $p > .25$, $\eta_p^2 < .01$; Age x Emotion, $F(1, 56) = .46$, $p > .25$, $\eta_p^2 = .01$. When the *New Food* event was presented second, a significant Age x Emotion interaction emerged, $F(1, 56) = 5.82$, $p = .019$, $\eta_p^2 = .09$. For the 10-month-olds, infants' looking time to the *Anger* and *Disgust* expressions did not differ, $t(28) = .99$, $p > .25$, $d = .36$. For the 14-month-olds, infants' attended significantly longer to the *Anger* expression compared to the *Disgust* expression, $t(17.09) = 2.35$, $p = .031$, $d = .86$ (for cell means, see Table 4.1). There were no significant main effects: Age, $F(1, 56) = 3.77$, $p = .057$, $\eta_p^2 = .06$; Emotion, $F(1, 56) = 1.17$, $p > .25$, $\eta_p^2 = .02$.

4.3.3 *Discussion*

As hypothesized, infants attended longer to the *Disgust* expression compared to the *Anger* expression following the *Toy Taken* event. Taken together with Experiment 1, this suggests that infants expect a person to express anger, compared to both a positive emotion (i.e., happiness) and another negative emotion (i.e., disgust). Interestingly, and contrary to our hypotheses, there were no significant interactions with Age. Thus, this is the first study to find that, between 10- to 14-months of age, infants can match different negative emotional expressions to specific events.

In contrast, younger 10-month-olds did not expect a person to express *Disgust* compared to *Anger* following the *New Food* event. One possibility is that infants were simply unable to perceive the difference between the anger and disgust expressions. This is unlikely, however,

given that infants in the first year of life can perceptually discriminate between and categorize these facial expressions (Ruba et al., 2017). A more likely explanation is that infants viewed each of the two emotions as equally appropriate responses to each of the events. In other words, 10-month-olds expected that the act of tasting a new food would elicit a negative emotion in general, rather than disgust specifically.

This study provided some evidence that 14-month-olds expected that tasting a new food would elicit disgust compared to anger. When the *New Food* event was presented second (after the *Toy Taken* event), 14-month-olds attended longer to the *Anger* expression compared to the *Disgust* expression. However, this effect was not found when the *New Food* event was presented first. A similar order effect with a different *New Food* event was previously reported in Experiment 3 of Ruba et al. (2019). Potential reasons for this order effect will be discussed further in the General Discussion.

4.4 **Experiment 3**

The goal of Experiment 3 was to confirm and extend these effects with another sample of 10-month-olds. Events were identical to those used in Experiment 3 of Ruba et al. (2019). These events were selected in order to (a) confirm that 10-month-olds could not match disgust expressions to disgust-congruent events, and (b) determine whether 10-month-olds could match anger expressions to another type of anger-congruent event. Specifically, a different *New Food* event as well as an *Unmet Goal* event were tested. The *New Food* event was similar to Experiment 2, except a different Actor fed the Emoter a bite of food. In the *Unmet Goal* event, the Emoter tried and failed to obtain an out-of-reach object. Prior work with these specific event found that 14- and 18-month-olds expected the Emoter to (a) express disgust, rather than anger, after the *New Food* event, and (b) express anger, rather than disgust, after the *Unmet Goal* event

(Ruba et al., 2019). Similar to Experiment 2, we hypothesized that 10-month-olds would not have specific expectations about the type of negative emotion to follow the *New Food* event. However, we hypothesized that 10-month-olds would expect the Emoter to express anger, rather than disgust, following the *Unmet Goal* event.

4.4.1 *Methods*

4.4.1.1 Participants

The current sample consisted of 50 (28 female) 10-month-old infants (M = 10.01 months, SD = .19, range = 9.63 – 10.42). Ten more infants are currently needed to finish the sample for this study. All infants were healthy, full-term, and of normal birth weight. Parents primarily identified their infants as Caucasian (70%, n = 30), multiracial (19%, n = 8). Approximately 9% of infants (n = 4) were identified as Hispanic or Latino. Participants were recruited in the same manner as Experiment 1. Three additional infants were tested but excluded from the final sample due to inattention during the familiarization events (n = 1) or procedural error (n = 2).

4.4.1.2 Design

The design of the study was similar to Experiment 1. Equal numbers of male and female infants were randomly assigned to one of two emotion conditions (between-subjects): *Anger* or *Disgust* (n = 30 per condition). Each infant watched two different videotaped events of an Emoter interacting with another person and an object (within-subjects): the *Unmet Goal* event and the *New Food* event.

4.4.1.3 Stimuli

Familiarization trials. The stimuli were identical to those used in Experiment 3 of Ruba et al. (2019). The familiarization trials involved two videotaped events of an "Emoter"

interacting with objects. Both events started with the Emoter introducing herself to the infant by looking at the camera and saying "Hi baby" in a pleasant tone of voice.

In the *New Food* event, another adult female (the "Actor") and Emoter sat at a table, facing each other. After introducing themselves, the Actor placed a spoon and bowl on the table and said to the Emoter, "I have some food, would you like a bite?" The Emoter responded, "I would." Then, the Actor dipped the spoon into the bowl and brought the food to the Emoter's mouth. The event ended when the spoon was in the Emoter's mouth.

In the *Unmet Goal* event, the Emoter placed a bowl, three balls, and tongs on top of the table. She looked at the camera and said, pleasantly to the infant, "I'm going to put some balls in my bowl." The Emoter picked up the tongs and used them to put two of the balls in the bowl. When she reached for the third ball, she "accidentally" knocked the ball out of reach towards the infant/camera. The Emoter leaned across the table and tried to reach the third ball, saying to the camera, with a neutral facial expression, "I can't reach it.

Test trials. The test trials were videotapes of the Emoter's emotional expression after each event. The onset of the Emoter's emotional expression occurred after she was fed the food (*New Food*) or after the Emoter unsuccessfully reached for the third ball (*Unmet Goal*). Facial and vocal expressions were displayed in the same manner described in Experiment 2. During the emotional expression, the Emoter maintained her gaze on the spoon and bowl (which was pulled away from her mouth) or the ball (which was on the table). These test videos were cropped so that only the Emoter and the object (i.e., spoon/bowl, ball) were present in the frame. Thus, the Actor was not present in the *New Food* test trial video. Full videos can be accessed here: https://osf.io/vsxm8/?view_only=2e149765de734f3bb7884369e01c9b9b. For validation information, see the Supplementary Analyses (page 146).

4.4.1.4 Apparatus and Procedure.

The apparatus and procedure were identical to Experiment 1, except that infants viewed the *Toy Taken* and *New Food* events.

4.4.1.5 Scoring

A second trained research assistant recoded 100% of the tapes offline, without sound. The coder was kept fully blind as to the participant's experimental condition and which emotion was presented to the infant. Agreement was excellent, $r = .99$, $p < .001$. Identical results are obtained using the online and offline coding (analyses with the offline reliability coding are reported below).

4.4.1.6 Hypothesis and Analysis Plan

Between-subjects analyses were planned separately for each event. If infants are able to form the predicted event-emotion matches, they should attend longer at the expression when it is incongruent with the event. Thus, after viewing the *Unmet Goal* event, infants should attend longer to the *Disgust* expression relative to the *Anger* expression. On the other hand, after viewing the *New Food* event, infants should attend longer to the *Anger* expression relative to the *Disgust* expression.

4.4.2 *Results*

All infants, across both conditions, attended to the entirety of the familiarization trials. A 2 (Emotion: anger / disgust) x 2 (Order: new-food first / unmet-goal first) analysis of variance (ANOVA) was conducted separately for each event.

4.4.2.1 Unmet Goal Event

There was a significant Order x Emotion interaction, $F(1, 46) = 5.36$, $p = .042$, $\eta_p^2 = .09$. Follow-up comparisons revealed that when the *Unmet Goal* event was presented first, infants'

looking time to the *Disgust* and *Anger* expressions did not differ, $t(23) = 1.18$, $p = .25$, $d = .34$. However, when the *Unmet Goal* event was presented second (after the *New Food* event), infants attended marginally longer to the *Disgust* expression compared to the *Anger* expression, $t(23) = 1.75$, $p = .093$, $d = .69$. There were no significant main effects: Emotion, $F(1, 46) = .26$, $p > .25$, $\eta_p^2 = .01$; Order, $F(1, 46) = .12$, $p > .25$, $\eta_p^2 < .01$ (for cell means, see Table 4.2).

4.4.2.2 New Food Event

There were no significant main effects or interactions: Order, $F(1, 46) = 1.65$, $p = .20$, $\eta_p^2 = .04$; Emotion, $F(1, 46) = .08$, $p > .25$, $\eta_p^2 < .01$; Order x Emotion, $F(1, 46) = .75$, $p > .25$, $\eta_p^2 = .02$ (for cell means, see Table 4.2).

4.4.3 *Discussion*

As with Experiment 2, the results suggest that 10-month-olds did not expect an Emoter to express disgust, rather than anger, after the *New Food* event. In contrast, the results provided some evidence that 10-month-olds expected an Emoter to express anger, rather than disgust, after the *Unmet Goal* event. Specifically, when the *Unmet Goal* event was presented second (after the *New Food* event), infants attended longer to the disgust expression compared to the anger expression. However, there were no differences in infants' looking times to the emotional expressions when the *Unmet Goal* event was presented first. These order effects are similar to those found in Ruba et al. (2019) and with the 14-month-olds in the *New Food* event of Experiment 2 (discussed in more detail below).

4.5 **General Discussion**

Together, these experiments explore how infants in the first year of life match negative emotional expressions to eliciting events. Experiment 1 found that 10-month-old infants expected an Emoter to express a negative emotion (anger), rather than a positive emotion

(happy), after a negative event (*Toy Taken*). This is the first study to demonstrate that infants in the first year of life can match negative emotional expressions to negative eliciting events. In contrast to prior work (Hepach & Westermann, 2013; Skerry & Spelke, 2014), infants in this study did not expect an Emoter to express a positive emotion (happiness), rather than a negative emotion (anger), after a positive event (*Toy Given*). As previously discussed, infants may have difficulty predicting a person's future behavior and emotions from receiving actions (Chiarella & Poulin-Dubois, 2013; Eason et al., 2018).

Experiment 2 and 3 built on these findings to explore whether 10-month-olds could match *specific* negative emotions to negative events. Findings revealed that 10-month-olds and 14-month-olds expected an anger-congruent event (*Toy Taken*) to specifically elicit anger, rather than disgust. Some evidence was provided that 10-month-olds could also form these matches with a different anger-congruent event (*Unmet Goal*). However, 10-month-olds did not expect a disgust-congruent event (*New Food*) to specifically elicit disgust, rather than anger.

It is important to note that several of these findings are qualified by order effects. In general, hypothesized effects were strongest when the target event was presented second. For instance, when the *New Food* event was presented second (after the *Toy Taken* event), 14-month-olds attended significantly less to the disgust expression compared to the anger expressions (Experiment 2). In addition, when the *Unmet Goal* event was presented second (after the *New Food* event), 10-month-olds attended significantly less to the anger expression compared to the disgust expression (Experiment 3). There were no differences in infants' looking times to the emotional expressions when the target event was presented first. Similar order effects were found with this paradigm in Ruba et al. (2019). The hypothesized effects may have been stronger in this order, because infants had more experience with the events/paradigm with the second set of

events. Further perhaps the familiarization period (i.e., two trials) was not long enough to sufficiently acclimate infants to the task. This could partially explain why infants had relatively long looking times (20-30s) to the test events. With a longer familiarization period (or a habituation design) in future studies, these effects may become more robust and reliable.

4.5.1 *Implications for Emotion Theories*

Returning to the debate on infants' emotion concepts, these findings seem to provide evidence against constructionist theories of emotion. These theories argue that young infants only interpret emotions in terms of valence (Barrett, 2017; Lindquist & Gendron, 2013; Widen, 2013). Ten-month-olds in the current studies matched positive and negative emotions to eliciting-events, and they also made some links between different negative emotions and specific eliciting-events. Importantly, this is the first study to explicitly test whether infants in the first year of life have some "understanding" of different negative emotional expressions. Prior research with this age has compared positive to negative emotions only (Hepach & Westermann, 2013; Mumme & Fernald, 2003; Skerry & Spelke, 2014; Vaillant-Molina & Bahrick, 2012; Walden & Baxter, 1989). For this reason, studies have been unable to determine whether infants' responses are valence-based (i.e., positive vs. negative) or reflect an understanding of specific emotions (i.e., disgust vs. anger). However, given the pattern of results obtained in the current studies, it appears that infants' emotion concepts in the first year of life, at least those related to anger, may be more refined.

These findings add to emerging evidence that preverbal infants are not limited to valence-based interpretations of emotional expressions (Ruba et al., 2017, 2019; Walle et al., 2017; Wu et al., 2017). According to constructionist theories, this should not be possible. These theories state that infants cannot "perceive" or "interpret" discrete negative emotional expressions until much

later in development, once children have gained experience with emotion labels, such as "angry" and "sad" (Barrett et al., 2007; Lindquist & Gendron, 2013). Importantly, using identical methods to the current experiments, Ruba et al. (2019) found that 14- and 18-month-old infants differentiated between the emotions of anger, fear, and disgust. Specifically, infants expected (a) disgust to be expressed following the *New Food* event, rather than anger and fear, and (b) anger to be expressed following the *Unmet Goal* event, rather than disgust and fear. Studies have also found that infants in the second year of life can link positive, within-valence emotional vocalizations to specific elicitors (Wu et al., 2017), as well as respond with different behaviors to specific negative emotional expressions (Walle et al., 2017). Together, these studies indicate that preverbal infants may begin to differentiate negative emotions on a conceptual basis as early as 10- to 14-months of age. Crucially, this narrowing starts to occur *before* infants acquire emotion language, not after (Barrett, 2017; Barrett et al., 2007).

4.5.2 *Developmental Changes in Infants' Emotion Concepts*

An open question relates to mechanism that prompts the differentiation of negative emotional expressions around the end of the first year of life. Early in development, infants have many opportunities to learn the link between their own emotions and typical eliciting events (Bennett, Bendersky, & Lewis, 2002). For example, newborns express a rudimentary form of disgust (i.e., distaste; Rozin & Fallon, 1987) when they taste something unpleasant (Rosenstein & Oster, 1988). In addition, by 8-months of age, infants express anger when an object is taken away or a goal is blocked (Lewis, Alessandri, & Sullivan, 1990; Stenberg, Campos, & Emde, 1983). Thus, perhaps certain social experiences are required for infants to understand these emotions.

One potential experience that may initiate infants' understanding of negative emotional expressions is the onset of self-produced locomotion (Campos et al., 2000). Specifically, the emergence of crawling and walking may provide infants with opportunities to link negative emotional expressions to specific eliciting events. Several studies have already documented the marked behavioral and social changes that occur during the transition from crawling to walking, which occurs around 12-months of age. The ability to walk allows infants to explore novel objects that are further away (Clearfield, 2011; Karasik, Tamis-LeMonda, & Adolph, 2011), carry objects in their hands (Karasik, Adolph, Tamis-LeMonda, & Zuckerman, 2012) , and direct their gaze at social partners (i.e., caregivers; Kretch, Franchak, & Adolph, 2014). Thus, walking changes the *types of social interactions* that infants have with other people. For example, crawling infants engage in more passive social observation (e.g., watching their mother and an experimenter interact) compared to walking infants, who engage in move active bids for social interaction (Clearfield, Osborne, & Mullen, 2008; Karasik et al., 2011). Further, mothers of crawlers are less likely to verbally respond to infants' social bids compared to mothers of walkers, who are more likely to provide action directives (e.g., "Put it there"; Karasik, Tamis-LeMonda, & Adolph, 2014).

In regards to emotional communication, specifically, one study found that mothers of walkers are less praising of infant behavior and engage in more repeated attempts to stop forbidden actions, compared to mothers of crawlers (Biringen, Emde, Campos, & Appelbaum, 1995). This study also found that parent and infant expression of both positive and negative affect increases from 10- to 14-months. Other studies have reported that parents begin to express different negative emotions as their infants start to crawl. For example, parents increasingly express anger as they attempt to control their infant's autonomous behavior, and, in return,

infants express anger and frustration when these goals are blocked (Campos, Kermoian, & Zumbahlen, 1992; Saarni et al., 2007). Parents also commonly express disgust in response to the child touching/mouthing certain objects and substances (Stevenson et al., 2010), which are now within the reach of a locomoting infant. Further, parents might express more fear now that their infants are able to put themselves into dangerous situations (e.g., a steep drop; Sorce et al., 1985). In contrast, infants in the first months of life seldom observe negative emotional expressions when engaged in face-to-face interactions with their mothers (Malatesta & Haviland, 1982) (Malatesta, Grigoryev, Lamb, Albin & Culver, 1986).

In all, the transition from crawling to walking sets off a cascade of social and emotional changes in infants' lives. Not only are infants able to interact more with their environment and their caregivers (e.g., Karasik et al., 2011; 2012; 2014), but infants also witness and express more negative emotions (Campos et al., 2000, 1992). These changes could partly explain why infants between 10- and 14-months of age are beginning to link different negative emotions to specific events.

4.5.3 *Future Directions*

Although these studies fill in heretofore missing information about the development of infants' emotion concepts, much is still unknown. To date, only a handful of studies have examined how infants in the first two years of life perceive and understand within-valence emotions (Martin et al., 2014; Reschke et al., 2017; Ruba et al., 2017, 2019; Sorce et al., 1985; Walle et al., 2017; Wu et al., 2017). More research is needed to determine when and how infants begin to make subtle distinctions between different emotional expressions. In this way, future research should also focus on identifying developmental change and the mechanisms of such change (e.g., transformations in social interactions that are concomitant with greater self-

locomotion). Multiple methods, from looking-time and social referencing paradigms to language-based tasks, could be used to test these questions with various age-groups. Longitudinal studies, especially microgenetic studies, could also be used to pinpoint when and how emotion concept understanding changes at particular points in infancy. Most importantly, the current studies underscore the importance of cross-disciplinary research between affective science and developmental psychology. The debate on the nature of emotion actively continues at a theoretical and empirical level (Barrett, Khan, Dy, & Brooks, 2018; Cowen & Keltner, 2017, 2018). Until now, research with young infants has been largely missing from this debate. However, by adding new data gathered from a developmental perspective, researchers can draw closer to answering some of the most basic questions about the nature, scope, and development of human emotion understanding.

4.6 **Supplementary Analyses**

4.6.1 *Emotion Validation Methods*

Sixty university undergraduates were recruited from the Psychology Participant Pool to validate the emotional expressions used in the current studies. Participants were given course credit in exchange for their ratings. Validation methods were identical to Ruba et al. (2019).

The videos were validated in an online survey. After consenting to participate, participants viewed one videotaped emotional expression (i.e., anger) from one of the events used in the Experiment 1 and 2 (i.e., *Toy Taken #1, Toy Given, New Food, Toy Taken #2*). Validation information for the events used in Experiment 3 were collected in a previous validation (Ruba et al., 2019) and are represented below. The expression was presented facially and vocally. Participants answered two questions to measure the *valence* of the emotional expression and the *arousal* level of the emotional expression. After answering the questions for

one video, the next video played until all videos were rated. The videos were presented in a random order.

The valence and arousal questions were adapted from the Self-Assessment Manikin (SAM; Bradley & Lang, 1994). We chose the SAM given that it is a non-verbal, pictorial measure, which reduces participants' reliance on language. Participants were asked, "How does this person feel?" and were prompted to select one of five pictures of a cartoon mannequin. For the valence ratings, the mannequin's facial expression ranged from a large frown (i.e., very negative) to a large smile (i.e., very positive). For the arousal ratings, the mannequin's expression ranged from closed eyes (i.e., very low arousal) to open eyes with an exploding chest (i.e., very high arousal). For analysis, participants' picture selections were recoded from 1 (i.e., very positive / high arousal) to 5 (i.e., very negative / low arousal). Ratings for each of the emotions were compared to "neutral valence" and "medium arousal" (i.e., a score of "3") in one-sample t-tests. Planned paired samples t-tests also compared the three emotions for the valence and arousal ratings. Means and standard deviations for the ratings are presented in Table 4.3.

4.6.1.1 Toy Taken Event (Experiment 1)

The anger expression was rated as more negative compared to neutral, $t(58) = 43.36$, $p < .001$, while the happy expression was rated as more positive compared to neutral, $t(58) = 14.49$, $p < .001$. The anger expression was rated as significantly more negative in valence than the happy expression, $t(58) = 18.96$, $p < .001$.

The anger expression, $t(58) = 3.57$, $p = .001$, was rated as significantly more arousing compared to medium arousal. The happy expression did not differ in arousal from "medium", $t(58) = .10$, $p > .25$. The anger expression was rated as significantly higher in arousal than the happy expression, $t(58) = 2.12$, $p = .037$.

4.6.1.2 Toy Given Event (Experiment 1)

The anger expression was rated as more negative compared to neutral, $t(58) = 37.30$, $p < .001$, while the happy expression was rated as more positive compared to neutral, $t(58) = 17.92$, $p < .001$. The anger expression was rated as significantly more negative in valence than the happy expression, $t(58) = 20.39$, $p < .001$.

The anger expression, $t(58) = 2.85$, $p = .006$, and the happy expression, $t(58) = 2.35$, $p = .022$, were rated as significantly more arousing compared to medium arousal. The anger expression was rated as significantly higher in arousal than the happy expression, $t(58) = 3.52$, $p = .001$.

4.6.1.3 Unmet Goal Event (Experiment 3)

All three expressions were rated as significantly more negative compared to neutral: anger, $t(58) = 10.13$, $p < .001$; disgust, $t(58) = 14.53$, $p < .001$; fear, $t(58) = 5.63$, $p < .001$. The fear expressions were rated as significantly less negative than the anger expressions, $t(58) = 2.94$,

$p = .005$, and the disgust expressions, $t(58) = 3.62$, $p = .001$. Ratings for the anger and disgust expressions did not differ, $t(58) = .71$, $p > .25$.

The anger, $t(58) = 3.37$, $p < .001$, and fear expressions, $t(58) = 4.90$, $p < .001$, were rated as significantly more arousing compared to medium arousal. Disgust expressions did not differ in arousal from "medium", $t(58) = .74$, $p > .25$. The disgust expressions were rated as significantly lower in arousal than the anger expressions, $t(58) = 3.38$, $p = .001$, and the fear expressions, $t(58) = 4.65$, $p < .001$. Ratings for the anger and fear expressions did not differ, $t(58) = .87$, $p > .25$.

4.6.1.4 New Food Event (Experiment 3)

There were no significant differences between the emotional expressions: anger compared to disgust, $t(58) = .80$, $p > 25$; anger compared to fear, $t(58) = .81$, $p > .25$; disgust compared to fear, $t(58) = 1.75$, $p = .09$. All three emotional expressions were also rated as significantly more negative compared to neutral: anger, $t(58) = 11.89$, $p < .001$; disgust, $t(58) = 14.49$, $p < .001$; fear, $t(58) = 10.34$, $p < .001$.

Only the fear expressions were rated as significantly more arousing compared to medium arousal, $t(58) = 5.77$, $p < .001$. Disgust expressions, $t(58) = .13$, $p > .25$, and anger expressions, $t(58) = .43$, $p > .25$, did not differ in arousal from "medium". The fear expressions were rated as significantly higher in arousal than the anger expressions, $t(58) = 4.09$, $p < .001$, and the disgust expressions, $t(58) = 4.65$, $p < .001$. Ratings for the anger and disgust expressions did not differ, $t(58) = .20$, $p > .25$.

4.7 Tables and Figures

Figure 4.1. Experiment 1 design. Test Trials are depicted for each Condition: (a) Happy, or (b) Anger.

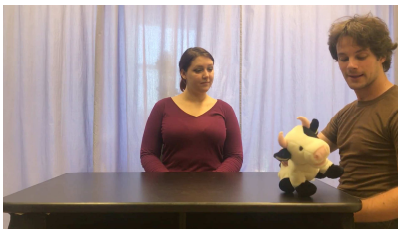
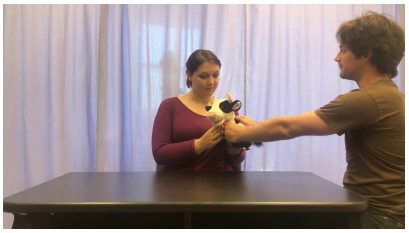
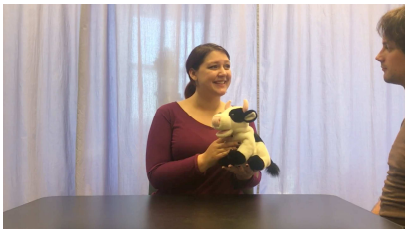
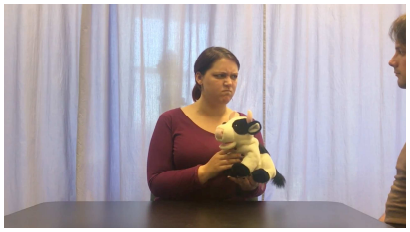
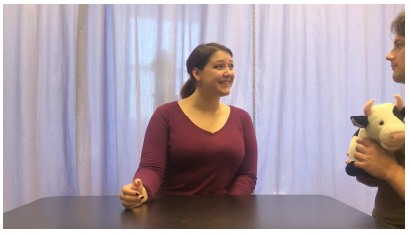
Event	Familiarization (x2)	Test
Toy Given	 	(a)  (b) 
Toy Taken	 	(a)  (b) 

Figure 4.2. Experiment 2 design. Test Trials are depicted for each Condition: (a) Anger, or (b) Disgust.

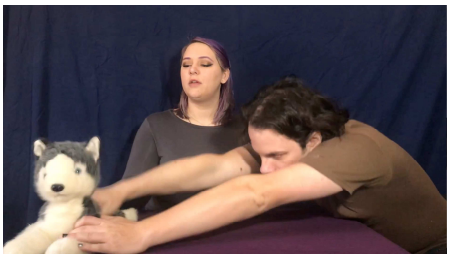
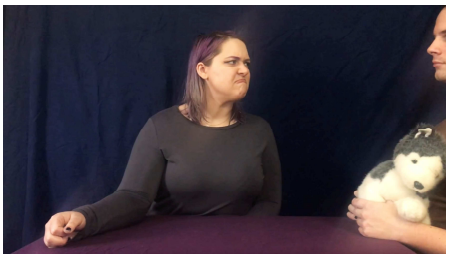
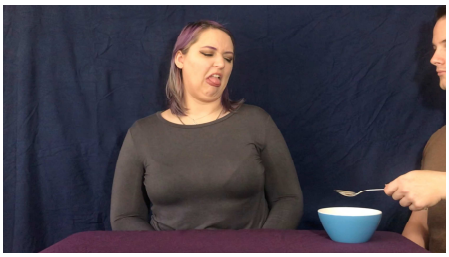
Event	Familiarization (x2)	Test
Toy Taken	 	(a)  (b) 
New Food	 	(a)  (b) 

Table 4.1. Experiment 2: Relevant cell means (and *SD*) of total looking time (in seconds) to the test events.

Event	Age	Order	Cell *n*	Anger	Disgust
	All	All	60	23.18 (13.59)	30.32 (17.97)
Toy Taken	10	All	30	22.00 (13.23)	28.39 (17.11)
	14	All	30	24.37 (14.07)	32.26 (18.88)
	All	All	60	27.92 (17.41)	25.45 (15.56)
	10	All	30	23.25 (17.53)	23.67 (14.98)
New Food	14	All	30	32.60 (16.25)	27.24 (16.17)
	14	Food-Take	15	32.31 (12.34)	34.33 (19.75)
	14	Take-Food	15	32.88 (19.86)	20.15 (6.64)

Table 4.2. Experiment 3: Relevant cell means (and *SD*) of total looking time (in seconds) to the test events.

Event	Order	Cell *n*	Anger	Disgust
	All	30	22.93 (9.78)	24.81 (16.27)
Unmet Goal	Food-Goal	15	19.70 (7.32)	29.24 (18.13)
	Goal-Food	15	26.17 (11.09)	20.36 (13.48)
New Food	All	30	23.33 (10.64)	22.47 (11.41)

Table 4.3. Means and standard deviations of validation ratings. Ratings range from 1 (i.e., very positive / high arousal) to 5 (i.e., very negative / low arousal).

	Valence Ratings			**Arousal Ratings**		
	Happy	Anger	Disgust	Happy	Anger	Disgust
Toy Taken (Exp 1)	1.41 (.75)	4.24 (.75)	N/A	3.02 (1.28)	2.51 (1.06)	N/A
Toy Given (Exp 1)	1.46 (.65)	4.10 (.85)	N/A	3.39 (1.27)	2.61 (1.05)	N/A
Unmet Goal (Exp 3)	N/A	4.05 (.80)	4.14 (.60)	N/A	2.56 (1.00)	3.08 (.88)
New Food (Exp 3)	N/A	4.19 (.63)	4.00 (.74)	N/A	2.95 (.92)	2.98 (.97)

Chapter 5. DISCUSSION

5.1 Summary of Dissertation

This dissertation presented three empirical papers that tested how 10-, 14-, and 18-month-olds categorize and interpret discrete emotional expressions. *Chapter 2* (Ruba et al., 2019) found that, by 14-months of age, infants can form event-emotion matches between *some* negative emotional expressions (e.g., anger vs. disgust) and specific eliciting events (e.g., an unmet goal vs. eating food). Across two experiments, infants as young as 14 months of age expected an Emoter to express disgust, rather than anger or fear, after tasting a new food. In addition, 14- and 18-month-old infants expected an Emoter to express anger, rather than disgust or fear, after failing to complete a goal. However, this latter effect did not replicate in a sample of 14-month-olds, suggesting that infants' understanding of the link between anger and unmet goals may be weak and somewhat unreliable at this point in development. Furthermore, neither 14- nor 18-month-olds expected an Emoter to express fear, rather than disgust or anger, after encountering an unfamiliar toy. This suggests different developmental trajectories may exist for different negative emotions, whereby infants have an earlier understanding of disgust elicitors compared to anger and fear elicitors. In all, these results suggest that matching negative emotions to specific events is an emerging ability in the second year of life, prior to the acquisition of emotion labels.

Chapter 3 found that 14- and 18-month-olds did not spontaneously form a superordinate category of negative valence across disgust, anger, and sad facial expressions. However, when a novel label ("toma") was added to each event in the habituation trials, infants were able to form this category. This effect was only found when infants were habituated to disgust and sad expressions (not when habituated to anger and sad expressions). The labeling effect was found

with two different stimuli sets, even when controlling for the amount of teeth displayed on the expressions. Interestingly, controlling for teeth seemed to reduce infants' ability to discriminate the happy facial expression from the negative facial expressions. This suggests that infants in the second year of life are still sensitive to salient facial features during emotion categorization tasks. Taken together, the results indicate that 14- and 18-month old infants show limited superordinate categorization of different negative emotional expressions, but that verbal labels can facilitate the formation of this abstract emotion category.

Chapter 4 examined potential developmental changes in event-emotion matching abilities between 10- and 14-months of age. Findings showed that 10-month-olds expected an Emoter to express anger, rather than happiness or disgust, after losing a desired object. Some evidence was also provided that (a) 10-month-olds expected an Emoter to express anger, rather than disgust, after failing to meet a goal, and (b) 14-month-olds, but not 10-month-olds, expected an Emoter to express disgust, rather than anger, after tasting a novel food. This is the first set of studies to show that infants in the first year of life can not only link negative emotions to negative events, but they can also link *specific* negative emotions to negative events. This ability is hypothesized to develop alongside self-produced locomotion late in the first year of life.

5.1.1 *Implications for Emotion Theories*

Returning to the debate on infants' emotion understanding development, findings from these experiments provide some support for both classical and constructionist theories. Recall that classical theories suggest that there is an innate, or easily acquired conceptual system for emotions (Ekman, 1994; Izard, 1994). In contrast, constructionist theories (Barrett, 2017; Lindquist & Gendron, 2013; Widen, 2013) predict that (a) preverbal infants have broad, valence-

based categories of emotional expressions, and (b) labels facilitate the division of these superordinate categories into basic-level categories (e.g., anger, disgust).

At face value, the current experiments seem to support classical emotion theories. These experiments found that infants between 10- to 18-months (a) were able to match specific negative emotional expressions to specific eliciting events (*Chapter 2* and *Chapter 4*), and (b) did not form a superordinate category of negative valence unless labels were included in the task (*Chapter 3*). Thus, by the second year of life, infants do not seem limited or predisposed to interpreting emotional expressions in terms of positive and negative valence. Instead, these findings suggest that discrete emotion understanding is emerging at this point in development. In particular, preverbal infants may be able to learn about some aspects of discrete emotional expressions (e.g., eliciting events, categories) around 10- to 18-months of age, before the acquisition of emotion labels. Thus, there appears to be an early emerging conceptual system for learning about discrete emotions.

However, the current studies also provide support for constructionist theories. In particular, labels were found to play an important role in constructing infants' emotion categories (*Chapter 3*). In addition, different contextual features (e.g., perceptual facial features, presentation order of events) influenced infants' performance in several experiments. This supports the constructionist argument that emotion perception is influenced by *context*, including language (Barrett, 2017). Relatedly, although preverbal infants may be able to learn about some aspects of discrete emotional expressions before the acquisition of emotion labels, their understanding of emotions is by no means "adult-like." Particularly for the event-emotion matching studies (*Chapter 2* and *Chapter 4*), effects were small and difficult to replicate. Further, infants did not form event-emotion matches for some of the events (e.g., *Strange Toy*). It

is unlikely that infants have a robust or fully formed understanding of emotions before acquiring emotion labels. In all, neither theory is able to completely account for the results in the current experiments.

5.2 A New Developmental Hypothesis

For this reason, these experiments support a revision of existing emotion theories in order to account for the emerging abilities of preverbal infants. In this section, I present a new, comprehensive developmental hypothesis that takes these findings into account:

At birth, infants' visual systems are not sufficiently mature to discriminate facial expressions (C. A. Nelson, 1987). However, by 6 months of age, infants should be able to visually discriminate between all pairs of facial expressions for "basic" emotions, including within-valence pairs (Schwartz et al., 1985). Differences in neural activity to different facial expressions may also emerge at this time. Although much less is known about how infants' discrimination of vocal expressions and body expressions, it is likely that these expressions follow a similar developmental sequence. In fact, infants may be able to auditorily discriminate between vocal expressions *before* they can visually discriminate between vocal expressions (Flom & Bahrick, 2007)

With increased brain maturation at around 7-months of age, infants begin to form *perceptual* categories for facial expressions. By the end of the first year of life, infants should be able to form perceptual categories for all pairs of facial expressions of "basic" emotions, including within-valence pairs (Ruba et al., 2017). Thus, I argue that infants develop the requisite perceptual and cognitive skills needed to discriminate and categorize "basic" emotional expressions in the first year of life. However, the ability to discriminate and categorize these discrete expressions (even at a neural level) does not require that infants attribute any affective

meaning to these displays. I argue that discrimination and categorization tasks likely test *perceptual* abilities, rather than infants' emotion *concepts,* particularly for facial expressions. Similarly, in the first year of life, infants should form intermodal matches between facial, vocal, and body expressions, both across- and within-valence. These tasks likely test infants' ability to detect regularities between emotional expressions in their environment, and also need not reflect any conceptual understanding of emotions.

In regards to infants' emotion *concepts*, I argue that infants' conceptual understanding of emotional expressions is initially broad, based on valence and arousal. This is congruent with constructionist theories (Barrett, 2017; Lindquist & Gendron, 2013) and research findings with preschoolers (Widen, 2013). It is unclear, however, *when* this broad understanding first emerges: it may be innately specified or gradually learned in the first year of life through observation of emotions in the infants' environment. In contrast to constructionist theories, I predict that around the second year of life, *but before emotion labels are learned*, this broad conceptual understanding of facial expressions gradually becomes more refined. Specifically, I argue that the acquisition of emotion labels is not necessary for infants to start to form event-emotion matches for within-valence emotions (Ruba et al., 2019; Wu et al., 2017). Further, it is possible that infants may begin to show differential responses to some within-valence emotions before emotion labels are learned (Walle et al., 2017).

Thus, in the second year of life, infants may understand something about the *causes, consequences,* and *functional behavioral responses* for discrete "basic" emotions. Infants could learn about these components of emotion understanding through observation of emotions in their environment, without needing to be explicitly taught these components via language. However, it is very unlikely that preverbal infants have robust or fully-formed discrete emotion concepts at

this age. Further, this emerging and rudimentary understanding of discrete emotions may be influenced by language. In other words, while emotion language may not be necessary for infants to discriminate, categorize, match, or respond to others' emotions, language may still play a constructive role in all of these abilities (e.g., language may change how emotions are categorized; Plunkett et al., 2008). Overall, this hypothesis is unique from current proposals in that it (a) clearly differentiates between individual components of infants' emotion understanding, and (b) emphasizes developmental change over the first two years of life. However, far more work is needed to empirically support this developmental sequence.

5.3 **Future Research Directions**

5.3.1 *Emotion Understanding in Infancy*

Although this dissertation provides initial empirical evidence for this developmental sequence, there are many unanswered questions relating to infants' emotion understanding. Critically, in order to determine whether infants are responding to emotional expressions beyond valence and arousal, much more research is needed on within-valence emotional expressions (e.g., anger vs. fear vs. disgust). Similarly, while most research on infants' emotion understanding has focused on facial expressions, studying vocal expressions, body expressions, and multimodal expressions would provide further ecological validity to these studies. Further, to create a truly "developmental" picture of emotion understanding, future research should examine infants at multiple ages. For example, discrimination, categorization, and intermodal matching abilities are primarily studied in the first year of life, whereas event-emotion matching and social referencing abilities are studied in the second year of life. For this reason, it is unclear how these abilities emerge and change over time, particularly as infants begin to learn emotion labels around 18-months of age (Bretherton, Fritz, Zahn-Waxler, & Ridgeway, 1986; Ridgeway et al.,

1985). This dissertation provides the first evidence that language influences infants' emotion categorization, and further work on this topic is likely a fruitful area of research.

In addition, relating these early emotion understanding abilities to individual and environmental factors could provide insights into the nature of these abilities (Peltola et al., 2018). For instance, recent research has linked the "fear bias" to multiple genetic variations (Forssman et al., 2014; Leppänen et al., 2011; but see Krol, Monakhov, et al., 2015), attachment security (Peltola, Forssman, Puura, van IJzendoorn, & Leppänen, 2015), maternal emotionality (de Haan et al., 2004; Forssman et al., 2014; but see, Leppänen et al., 2018), breastfeeding experience (Krol, Rajhans, et al., 2015), and child temperament (Nakagawa & Sukigara, 2012; but see, Forssman et al., 2014). These findings suggest that the "fear bias" may reflect a true "understanding" of the threat-signaling value of fearful expressions, based on environmental experience or more "innate" factors. However, more research is needed to confirm that these studies are measuring a fear bias, specifically, as opposed to another construct (e.g., a negativity/threat bias, sensitivity to novelty; Morales et al., 2017). This research could further speak to the debate between classical and constructionist theories over the early preparedness to process negative emotional expressions.

5.3.2 *Learning Mechanisms and Emotion Concept Development*

It is important to note that, although classical and constructionist theories disagree over the developmental course of emotion understanding in infancy, *both theories agree* that emotion understanding undergoes some degree of developmental change throughout childhood. However, little is currently understood about the developmental processes or mechanisms driving this change. Two learning mechanisms that are particularly relevant to explore in future research are *supervised learning* and *unsupervised learning* (Love, 2002). These two learning mechanisms

are adapted from machine learning concepts. In *supervised learning*, or "learning from examples", algorithms are trained with input paired with the correct output. For instance, "FaceReader," an emotion recognition software program, was trained with 10,000 pictures of facial expressions paired with emotion labels (Loijens & Krips, 2018). In *unsupervised learning*, algorithms are only given input (e.g., facial expressions). The algorithms must identify underlying patterns in the input to generate meaningful output (e.g., emotion categories). Children use both of these learning mechanisms to acquire emotion concepts.

Supervised learning focuses on teaching children emotion concepts. The "input" (e.g., facial expressions) is paired with correct "output" (e.g., emotion labels; LaTourrette & Waxman, 2019). A large body of work has documented how parents socialize emotion concepts through conversations with their children (Eisenberg, Cumberland, & Spinrad, 1998). In these conversations, parents not only label emotions, but they also discuss causes, consequences, and appropriate behavioral responses for emotions (Denham et al., 1994; Garner, Dunsmore, & Southam-Gerrow, 2008). Teachers play a similar role in socializing emotions with their young students (Ahn, 2005). In addition, posters and books in schools illustrate how different emotional facial expressions are supposed to look (e.g., "a happy face"). Children may also be able to learn about emotions and emotion labels through overhearing others' conversations (Akhtar, Jipson, & Callanan, 2001). In all, supervised learning is a largely language-dependent process.

In contrast, with *unsupervised learning*, or statistical learning (Saffran, Aslin, & Newport, 1996), children notice naturally occurring patterns in their environment and use these regularities to form categories and make predictions. In this case, the relationship between the "input" (e.g., emotional expressions) is categorized through its contextualization with previous experience. For instance, infants can (a) detect regularities in another person's emotional

expressions, and (b) use that information to predict the person's future behavior (Repacholi, Meltzoff, Hennings, et al., 2016; Repacholi, Meltzoff, Toub, et al., 2016). It has also been shown that older, verbal children and adults pick up on regularities in their emotional environments and use that information to adjust their emotion categories (Plate, Wood, Woodard, & Pollak, 2018; Pollak & Kistler, 2002).

Returning to the emotion theories, both classical and constructionist theories make different predictions about the relative importance of these learning mechanisms to emotion concept development. In particular, constructionist theories argue that language-dependent processes (i.e., supervised learning) drive the formation of emotion concepts (Lindquist & Gendron, 2013). In fact, the "theory of constructed emotion" argues that emotional facial expressions occur with such unpredictability that unsupervised learning of emotion concepts would be difficult, if not impossible (Barrett, 2017). However, classical emotion theories have largely advocated for the unsupervised learning of emotions, arguing that discrete emotional expressions are universal and do not need to be "taught" (Ekman, 1994, 2017).

5.3.2.1 Children from Atypical Emotional Environments

It is unclear which learning mechanism best accounts for developmental changes in emotion concepts in early childhood. Disentangling these mechanisms is difficult, given that typically developing children are often exposed to positive, invariant emotional environments from birth (Haviland & Lelwica, 1987). Thus, in order to determine the effect of environmental influences on emotion concept development, one possibility is to study children from atypical emotional environments. For example, the emotional environments of physically abused children significantly differ from those of typically developing children (Plate et al., 2019). Abusive parents report feeling more angry and overtly expressing anger compared to non-abusive parents

(Pollak, Messner, Kistler, & Cohn, 2009). However, these anger expressions are less intense than "prototypical" anger facial and vocal expressions (Camras et al., 1988). In turn, these less intense expressions are related to increased symptoms of anxiety, depression, and externalizing behaviors in children (Shackman et al., 2010). Further, many studies have found that physically abused children also have impairments in emotion understanding abilities (Camras et al., 1990; Luke & Banerjee, 2013; Perlman, Kalish, & Pollak, 2008; Pollak, Cicchetti, Hornung, & Reed, 2000; Shipman & Zeman, 1999).

One possibility is that these unpredictable, anger-prone emotional environments prevent typical *unsupervised learning* of emotions. Studies have shown that physically abused children have perceptual and attentional biases towards anger facial expressions (Pollak & Kistler, 2002; Pollak & Sinha, 2002). Compared to typically developing children, physically abused children also have a poorer understanding of the causes of anger expressions (Perlman et al., 2008; Pollak et al., 2000). Given that physically abused children are frequently exposed to anger expressions, these children may have difficulty using statistical learning strategies to predict when a person would "typically" express anger.

Another possibility is that physically abusive parents engage in less *supervised learning* of emotions with their children. In particular, studies have found that physically abusive mothers engage in less emotional discussion (i.e., fewer conversational turns about emotion understanding) than non-abusive mothers (Shipman & Zeman, 1999). Physically abusive mothers also provide less validation and emotion coaching about their children's emotions compared to non-abusive mothers (Shipman et al., 2007). Thus, physically abused children may have poorer emotion understanding because they are not explicitly taught about emotions (e.g., labels, causes, consequences, etc.). Constructionist theories argue that unsupervised learning of

discrete emotion concepts (e.g., anger vs. fear) may not be possible without exposure to emotion language (Barrett, 2017). Therefore, physically abused children's emotion understanding may be better predicted by a lack of emotion socialization (*supervised learning*) rather than emotional unpredictability (*unsupervised learning*). In fact, a study with *neglected* children found that maternal emotion talk alone, but *not* maternal negative affect alone, predicted children's emotion-understanding skills (Edwards, Shipman, & Brown, 2005). This result may not be surprising, however, given that neglected children do not receive much emotional information from their parents (Bousha & Twentyman, 1984).

In conclusion, studying children from atypical emotional environments, who are frequently exposed to negative emotional expressions (e.g., anger), would provide a much-needed test of supervised and unsupervised learning mechanisms. Such studies could further support or refute classical and constructionist theories of emotion concept development. For example, if maternal talk about emotions predicted more variability in children's emotion understanding than maternal negative affect, then the role of language and *supervised learning mechanisms* to children's emotion understanding development would be strengthened (Barrett, 2017; Lindquist & Gendron, 2013).

5.4 **Methodological Recommendations**

Given the relative dearth of research on infants' understanding of emotional expressions—particularly related to *emotion categorization* and *event-emotion matching*—novel methodological designs were needed for this dissertation. Here, based on my experience with these methods, I provide some methodological recommendations for future research.

5.4.1 *Event-Emotion Matching (Chapter 2 and 4)*

Prior research on event-emotion matching has varied widely in methodology. For instance, in the familiarization period, studies have either had no familiarization period (Hepach & Westermann, 2013), one familiarization trial (Reschke et al., 2017), or five familiarization trials (Skerry & Spelke, 2014). Similarly, for the test events, studies have presented infants with static facial expressions (Reschke et al., 2017), dynamic facial expressions (Hepach & Westermann, 2013), or bimodal facial and vocal expressions (displayed by non-human agents; Skerry & Spelke, 2014). For the studies of *Chapter 2* and *Chapter 4*, I used two familiarization trials and dynamic, multimodal emotional expressions. Multimodal expressions were chosen to maximize ecological validity. However, perhaps due to their dynamic nature, infants still maintained relatively high looking times to these expressions during the test trials (around 20-35s). This may also indicate a need for a longer familiarization period in future studies. A habituation paradigm could also be used, but this would preclude a within-subjects design.

These design changes could also eliminate the issue of order effects, which were present in several studies. In general, hypothesized effects were strongest when the target event was presented second. For instance, in Experiment 1 of *Chapter 2*, when the *Unmet Goal* event was presented first (before the *New Food* event), there were no significant differences between infants' looking time to the three emotional expressions. However, when the *Unmet Goal* event was presented second (after the *New Food* event), infants attended significantly less to the Anger expression compared to the disgust and fear expressions (see Supplementary Analyses, page 65). Similar order effects were found in Experiment 3 of *Chapter 2* and Experiment 2/3 of *Chapter 4*. Perhaps the hypothesized effects were stronger in this order because infants had more experience

with the events/paradigm with the second set of events. This provides further support for a longer familiarization period or habituation paradigm in future studies.

5.4.2 *Emotion Categorization (Chapter 3)*

Past research on emotion categorization has also varied widely in methodology. For example, studies differ in the number of models/people shown during habituation, from as few as two models (C. A. Nelson et al., 1979) to as many as eight models (R. F. Caron et al., 1985). Presenting infants with a large number of exemplars (i.e., more than six) during habituation has been found to hinder categorization (Casasola, 2005b). In fact, studies that have failed to find evidence of emotion categorization have typically used eight exemplars during habituation (R. F. Caron et al., 1985; Phillips et al., 1990). These studies may have *underestimated* infants' emotion categorization abilities by creating a cognitively challenging task. In addition, while some studies on emotion categorization have included a "familiar" trial (i.e., an event seen during habituation) in the test events (e.g., Ruba et al., 2017), most studies have not (e.g., Kestenbaum & Nelson, 1990; Ludemann & Nelson, 1988; Serrano et al., 1995). Instead, these studies compare infants' looking times to the novel test events with their looking times to the "criterion" trials (i.e., the last two habituation trials). Given that infants' looking to the final habituation trials is designed to be low, these studies may have *overestimated* infants' dishabituation to the novel test events (Oakes, 2010), and, as a result, overestimated infants' ability to form emotion categories.

Instead, the studies presented in *Chapter 3* likely provide a conservative test of infants' emotion categorization abilities. In these studies, infants were habituated to *six* different events (i.e., three people expressing two emotions). A stringent habituation criterion was used: 50% decrease in looking time from initial look, a fixed window of 3 trials, and 2s look away time.

Test trials included four different events, including a "familiar" event, presented in a counterbalanced order. Taken together, these methodological choices maximized the number of infants who actually habituated and avoided regression to the mean effects (Oakes, 2010). However, these choices may have also contributed to a higher attrition rate (especially with the 18-month-olds in Experiment 1). Additionally, these choices may have increased the complexity of the task, thereby underestimating infants' ability to form superordinate emotion categories. Future research may consider the following methodological changes: (a) a sliding habituation window, rather than a fixed window, (b) a look away time less than 2s (e.g., 1s; Casasola, 2005a), (c) presenting the familiar event first in the test trials, rather than counterbalancing the order of events (Oakes, 2010), and/or (d) using fewer events during habituation (e.g., one or two people expressing two emotions).

The studies presented in *Chapter 3* also highlight the importance of stimuli selection in emotion categorization research. In pilot testing for Experiment 1, we found that infants dishabituated to fearful facial expressions: a finding that was consistent with prior research (R. F. Caron et al., 1982; Ludemann & Nelson, 1988; C. A. Nelson et al., 1979). Given that infants are known to have a priori preferences for fearful facial expressions, I recommend the use of other negative facial expressions (e.g., anger, sadness, disgust) in future research. Testing other negative emotional expressions would also broaden our knowledge of infants' emotion understanding, given that most discrimination, categorization, and social referencing studies have compared happy expressions to fearful expressions.

Furthermore, researchers should consider the role of salient facial features in infants' emotion categorization. From the current experiments and prior research (R. F. Caron et al., 1985; Kestenbaum & Nelson, 1990), it appears that infants in the first two years of life will

attend to salient facial features (e.g., amount of teeth shown) when categorizing facial expressions. Future research, if it intends to test constructionist claims about infant emotion understanding, will need to take these features into account (Barrett, Adolphs, Marsella, Martinez, & Pollak, 2019). Unfortunately, to my knowledge, popular databases of facial expressions, including the Radboud Faces Database (Langner et al., 2010) and the Karolinska Directed Emotional Faces (Lundqvist et al., 1998), do not control for these features. In contrast, the NimStim Set of Facial Expressions (Tottenham et al., 2009) contains both open mouth and closed mouth facial expressions, and, for this reason, was used for *Chapter 3*. In the future, researchers may also consider developing sets of facial expressions that systematically vary these facial features.

5.5 **Conclusion**

In this dissertation, I presented eleven experiments on the development of emotion understanding across the first two years of life. These experiments are the first to directly address several research questions, including: (a) whether infants can form event-emotion matches with different negative emotions, (b) whether infants can form superordinate categories of negative valence, and (c) how labels impact emotion categorization in infancy. Critically, this dissertation differs from prior research in its focus on high arousal, negative emotional expressions (i.e., anger, fear, disgust). Such contrasts are necessary to determine whether infants are responding to emotional expressions based on valence (e.g., positive vs. negative) or based on discrete emotions (e.g., happy vs. fear). This dissertation also adds to the small body of research that examines emotion categorization and event-emotion matching in the second year of life (Hepach & Westermann, 2013; Reschke et al., 2017; Ruba et al., 2017; Wu et al., 2017). By studying

these older infants, developmental psychologists can paint a more complete picture of how emotion understanding changes and develops over time.

Overall, the goal of this dissertation is to advocate for increased collaboration between developmental and affective science. For instance, affective scientists would benefit from a more precise description of preverbal infants' emotion concepts. It is not accurate to conclude that preverbal infants are unable to "interpret" or "perceive" discrete negative expressions (Lindquist & Gendron, 2013; Shablack & Lindquist, 2019; Widen, 2013), nor is it sufficient to say that preverbal infants "understand" or "recognize" emotional expressions (Izard, 1994). Interpreting the literature in this way ignores the nuances and complexities of infants' emotion understanding abilities. Moving forward, descriptions of infants' emotion understanding should include information about (a) the component being measured (e.g., categorization, intermodal matching), and (b) the emotion contrasts tested (e.g., across- or within-valence). Distinctions about whether an ability is "perceptual" or "conceptual" must be made with caution, as most infant paradigms cannot make this distinction (Madole & Oakes, 1999). Furthermore, given that very little research has examined within-valence emotions, it is premature to make any definitive claims about infants' ability to perceive and understand discrete emotional expressions.

In addition, developmental psychologists would benefit from a deeper consideration of theoretical issues in affective science. Infants are an ideal test case to isolate the relative roles of evolution, language, and social experience in the development of emotion understanding. Although most infancy studies have not been designed to inform emotion theories, this has changed in recent years. This dissertation adds to a small, but growing, number of studies examining infants' understanding of within-valence emotional expressions (Knothe & Walle, 2018; Reschke et al., 2017; Ruba et al., 2017, 2019; Walle et al., 2017; White et al., 2019; Xie et

al., 2019). With this increased empirical attention and cross-discipline communication, researchers can turn towards collaborative projects to answer fundamental questions about the nature of human emotions.

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