EXAMINING THE PERCEPTION OF FACIAL EXPRESSIONS IN CHILDHOOD

EXAMINING THE PERCEPTION OF EMOTIONAL FACIAL EXPRESSIONS IN EARLY CHILDHOOD

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LAY ABSTRACT

Humans are experts at reading faces. Specifically, they are capable of interpreting complex social information from faces, including emotions, and using this information to navigate social situations. In order to organize facial emotional information, humans use a mechanism called categorical perception to quickly and efficiently sort facial emotional information into discrete categories. Inferences can be made about members within a category, which aids in the prediction and production appropriate behaviours. However, there has been limited research into the development of categorical perception in early childhood. The key goal of this thesis was to develop infant and toddler appropriate methodologies that capture the development categorical perception. In this thesis, I found that categorical perception does not develop uniformly across all ages and between different emotions. Results suggest that perceptual sensitivity to differences in facial emotional expression may be influenced by the use of emotion labels, or vice versa.

ABSTRACT

Adults perceive basic emotional facial expressions as discrete categories using categorical perception. Within categorical perception, discrimination of facial emotional expressions is better for *between* category faces than *within* category faces. In this thesis, I examined the developmental trajectory of categorical perception in early childhood. I also examined the relationship between sensitivity to physical differences in facial emotional expressions and the use of emotion labels in toddlers. In Chapter 2, I found that infants before 12-months failed to discriminate *between* category faces along a happy-sad continuum. In contrast, evidence suggest that 9- and 12-month old infants categorically perceived faces along a happy-angry continuum. These findings suggest that categorical perception may not develop concurrently for all emotions. In Chapter 3, I found that toddlers by 26-months of age categorically perceived faces along a happy-sad continuum. These results highlight the long developmental trajectory of categorical perception of facial emotional expressions across early childhood. In Chapter 4, I found a relationship between perceptual sensitivity to physical differences between happy and sad faces, and the emotion vocabulary size in 26-month-olds. This relationship suggests that learning about emotions may utilize information from multiple domains, and that learning in one domain may influence the development of another. The perception of facial emotional expressions is an essential component of early social emotional development. Categorical perception is a mechanism that aids in organizing complex social information from faces into actionable categories. The research in this thesis advances our understanding of early social perceptual development and the process that allow us to successfully navigate in the social world.

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"It takes a village…"

A recent article by Peterson (2015) described the unique process of collecting, analyzing, and producing publishable data within the field of developmental psychology. As an observer in developmental labs across North America, the author described developmental psychology research as arduous, resource-exhausting, labour-intensive, and risky in terms of yielding enough data to be publishable. Really, it's a wonder how anyone in our field completes a doctorate at all! There are no guarantees that infant and toddler participants will cooperate when they come in for studies. We do not have the luxury of providing commands and expecting compliance from a 6-month-old or a 24-month-old. We deal with sleepy, hungry, burpy, and grumpy children, all while trying to collect clean and usable data. It truly takes a team of people to schedule, reschedule, and run infant-based experiments.

Therefore, it should be noted that the successful completion of this thesis was heavily dependent on the generosity of local families, but also the dedication, enthusiasm, and gumption of an amazing team of thesis students, directed-lab students, and student volunteers. Together, we ran a total of 500 infants between the ages of 6-months to 24-months, and finished 5 studies in a span of 5 years. I asked everything of them, and never once did they let me down. I was continually encouraged and inspired by their intelligence and confidence, and it was an honour to mentor each and every one of them. I am so incredibly proud of everything they have accomplished and I look forward to hearing about and seeing their future successes.

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CONTRIBUTIONS

This thesis consists of three manuscripts produced in collaboration with my supervisor, Dr. M.D. Rutherford. I was directly responsible for the experimental design, collection of data, analysis, and interpretation of all data for the experiment reports. Chapter 2 is a manuscript that has been published in the journal *Infant Behavior and Development.* Chapter 3 is a manuscript that is currently under review at the journal of *Infant Behavior and Development.* Chapter 4 is a manuscript that is currently under review at the *European Journal of Development Psychology*. I was responsible for the preparation, theoretical implications, and development of all three manuscripts.

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CHAPTER 1

INTRODUCTION

Humans are experts at processing faces. They can recognize thousands of individual faces and can quickly recognize a variety of expressions. The ability to process face information supports social interactions. For example, facial expressions often convey important social information about an individual's internal state, including their thoughts, emotions, and desires. Having an understanding of another's internal state aids in the prediction and interpretation of behavior, and in turn this helps humans modulate their own behavior. Therefore, the ability to perceive and interpret facial information is an important skill that helps humans navigate a complex social environment.

Given the importance of faces to communication, it is not surprising that attention to faces begins early in development. From birth, infants tend to preferentially look at faces (Farroni, Menon, Rigato, & Johnson, 2007; Valenza, Simion, Cassia, & Umilta, 1996;), although factors like top-heaviness, congruency, and contrasts may be sufficient to explain the preference (Johnson, Dziurawiec, Ellis, Morton, 1991; Mondloch et al., 1999). Further, evidence suggests that infants can differentiate among some emotional facial expressions depending on the method used to test discrimination and the order of presentation of faces during test. For example, 3-month-old infants can discriminate between happy and frowning facial expressions (Barrera & Maurer, 1981), 3-month-olds can discriminate between happy and surprised expressions (Young, Browne et al, 1977), 3-month-olds cannot discriminate between happy-sad expressions (Young, Browne et al, 1977-regardless of presentation order), and 4 to 6-month- olds can discriminate between angry and fearful expressions (Serrano, Iglesias, & Loceches, 1992). In contrast, some studies have found that 5-month-olds can discriminate between fear and sad, but not fear and angry expressions (Schwartz, Izard, & Ansul, 1985). Given the variable literature, it seems likely that discrimination of facial emotional expressions has a long developmental trajectory. In fact, sensitivity to facial emotional expressions improves throughout childhood, with different rates of development for different facial expressions (Gao & Maurer, 2009; Gao & Maurer, 2010),

Categorical Perception

One adaptive strategy that allows efficient processing of social information is categorical perception. Although stimuli may be presented as physically continuous, the human visual system does not perceive information continuously, but rather groups information into categories. Categorical perception is quick and automatic, yielding categories during the process of perception. Once information has been categorized, inferences can be made about within category exemplars. Categorical perception has been documented in several domains including in the perception of language (Liberman, Harris, Hoffman, & Griffith, 1957), music (Burns & Ward, 1978), colour (Bornstein & Korda, 1984) and most importantly, facial emotional expressions, and these domains have been well studied in adults (Etcoff & Magee, 1992; Calder, Young, Perrett, Etcoff, & Rowland, 1996).

Bornstein & Korda (1984), studied categorical perception of colours using a continuum created with the colours, blue and green. First, participants were tested on their ability to identify each exemplar as blue or green by pressing one of two labeled buttons. In a matching task, participants saw pairs of exemplars that were within a category or between categories, and were asked to make a judgment on whether they were the same or different. Reaction times (RT) were measured across all tasks. Results for the identification tasks indicated that participant's partitioned the stimulus continuum into two discrete colours. The boundary or crossover point in identification was situated at the midpoint of the continuum, which was consistent with previous work (Bornstein & Monroe, 1980). Further inspection of the RTs for identification demonstrated that slower responses occurred for the midpoint stimulus, and faster responses occurred for stimuli that were furthest from the boundary, suggesting that despite the stimuli being equidistant, category information influenced perception. RT for responses to the matching task indicated that responses to "same" category colours were faster for pairs of stimuli with the same label (i.e. within category) than for pairs of equidistant stimuli with different labels (i.e. between categories). Taken together, results demonstrated that despite the continuous nature of the stimuli presented, the perception of the continuum was categorical.

In theory, the continuum between blue and green should represent a continuous colour stream that gradually changes from one hue to another. Yet the perception of the continuum indicates that equidistant exemplars are viewed more "alike" when they are within the same labelled category and the differences are enhanced when they fall between categories. Up to the early 1970s, most of the work in categorical perception of facial expressions involved one-dimensional line figure faces but computer graphics and advanced programs have made it possible for morphed continua between facial emotional expressions.

There is limited research on the developmental trajectory of categorical perception of facial emotional expressions. First, we do not know when categorical perception emerges. Second, it is unclear whether categorical perception develops at the same time for all facial emotional expressions. Finally, the literature alludes to the relation between early social perception of emotional stimuli and later social cognitive abilities (Phillips, Wellman, Spelke, 2002; Vaish, Grossman, & Woodward, 2008; Petola, Forssman, Purra, va IJzendoorm, & Leppanen, 2015), yet this link has not been explored in depth. This thesis will explore the development of categorical perception of facial expressions across the first year of life, and examine its relation to other social cognitive skills later in development.

Research standards for categorical perception in adults

Empirically, there are two possible standards of evidence to infer categorical perception. Under the stricter, categorical perception occurs when an individual perceives members of the same labelled category as the same, with no detection of changes within categories (Studdert-Kennedy et al., 1970, p.234). However, this is rarely found in most domains in which categorical perception is studied, since adults can often detect differences between members of the same category (e.g. two blues, or two happy expressions). For the purposes of this thesis and because it is widely accepted within the literature (Pisoni & Tash, 1974; Harnard, 1987a), a more lenient definition of categorical perception will be used when seeking evidence of categorical perception. Here, categorical perception will be inferred when "there is a quantitative discontinuity in discrimination at the category boundaries of a physical continuum, as measured by a peak in discriminative acuity at the transition region for the identification of members of adjacent categories" (Harnad, 1987a, p. 3); discrimination between items/stimuli is most accurate at the category boundaries where a change in identification of category membership also occurs.

The measure of categorical perception relies on an individual's perception of, and ability to discriminate, stimuli along a continuum. The perceptual distance between stimuli can be measured in a number of ways including explicit labeling and reaction time or accuracy in a discrimination task (Repp, 1984). Typically, categorical perception is studied using a continuum of stimuli where each adjacent pair of images are physically equidistant and the continuum spans a category boundary. Participants must perform two tasks: an identification task and a discrimination task.

The identification task involves having an individual provide a category label for randomly presented stimuli along the continuum. Typically, individuals are given two category labels that best describe the end-points of the continuum, and are required to choose which one of the two labels best fits the stimuli (2-alternative-forced-choice experimental paradigm; Etcoff and Magee, 1992). Other studies use free response: participants are provided with the stimuli and are asked to respond with a description of the facial emotional expression in their own words (Etcoff and Magee, 1992, Calder et al., 1996). Reaction time may be measured in identification tasks (Bornstein & Korda, 1984; de Gelder, Tuenisse, & Benson, 1997). In these studies, participant reaction time in identifying stimuli along the continuum is measured. Typically, reaction time is fastest when identifying stimuli that are further away from the category boundary than when they are closer to the boundary.

The discrimination task tests an individual's ability to discriminate pairs of stimuli that span the category boundaries compared to those that are within a category. Performance can be measured by accuracy or reaction time. For example, participants in some studies have been presented with two images from the continuum (image A and image B) sequentially and then are tasked with determining whether a third image (image X) matches image A or B (Calder et al, 1996; Etcoff & Magee, 1991; Repp, 1984). Alternatively, discrimination can also be assessed by presenting participants with two faces from the continuum simultaneously, and asking them to make a judgment about whether they are the same or different (Calder et al, 1996).

Results from the identification and discrimination tasks are used together to infer whether there is evidence of categorical perception (Harnad, 1987; Repp, 1984; Studdert-Kennedy, Liberman, Harris, & Cooper, 1970). The identification task determines the category boundaries for a continuum, and the discrimination task tests whether discrimination is more accurate for between category stimuli than within category stimuli. Both tasks are required because the category boundaries found within the discrimination task must be confirmed using performance on the identification task. Only when the peak performance in the discrimination task occurs at the same location as the 50% point in the identification tasks, can a case be made that the category boundary has been identified and that categorical perception has occurred. Thus, performance on a single task cannot accurately assess categorical perception because identification of stimuli along the continuum must be better between and not within the category boundary as set by the discrimination task.

For example, in adults, responses from the identification task are graphed along a curve where the exemplars along the continuum are represented along the x-axis and the percent responses are on the y-axis. For categorical perception to be inferred, it would be expected that the graph would represent an “s-shaped” curve such that a rapid change in responses (i.e. labeling) for one category to another occurs across the midpoint (50%), where the stimuli are maximally ambiguous. This point of rapid change in responses, or peak in performance, is usually inferred as the category boundary. The peak performance demonstrates that it is easier to differentiate stimulus when they across the perceptual category boundary than when they are the same physical distance within a category. Once the category boundary has been determined by the identification task, participants are asked to make discriminations of stimuli within and between categories. If discrimination is more accurate for stimuli between categories rather than within categories, then categorical perception is inferred.

The reasoning behind this is that the function of categorical perception is presumed to allow for efficient organization of information from the environment into discrete categories. Once information has been categorized, superficial variations between same category exemplars are deemphasized (Gladstone & Hendrickson, 2009). In contrast, differences are exaggerated for between category exemplars, even though each exemplar along a continuum is equidistant in terms of their physical differences. Hence, identification of stimuli along the continuum should demonstrate that the exemplars are being sorted into discrete categories. Following this demonstration, detection of differences of stimuli between category boundaries should be better than within category boundaries. This mechanism of categorical perception is useful in making connections between things that have different apparent forms. For example, flowers and trees are both plants, but if one were to categorize them into their distinct categories (flowers vs. trees), than nonessential differences within a category (i.e. blue flower vs. red flower) do not matter as much. Although they trigger slightly different representations, the core information will be the same (both blue and red flowers will still have the same property as all flowers).

Categorical perception of facial emotional expressions in adults

The first study of categorical perception of facial expressions in adults used computer-generated line-images of expressions (Etcoff and Magee, 1992). Continua were created depicting the following emotions: happiness, sadness, fear, anger, and disgust. Participants performed an identification and a discrimination task using a continuum of physically equidistant facial expressions. Eight continua were made using facial emotion expressions including: 3 continua using easily discriminated emotions (e.g. happy-sad, angry-afraid, and angry-sad), 2 continua using commonly confused emotions (e.g. surprised-afraid, and angry-disgusted), 2 continua with neutral faces (e.g. happy-neutral and sad-neutral), and 1 continuum using happy-surprised faces. In Etcoff and Magee, 1992, the discrimination task required participants to make judgments on whether a picture, “X”, depicting a facial expression along a continuum was identical to one of two previously displayed expressions “A” or “B”. The identification task involved the participant to choose one of two labels for the face or to provide their own description of the expression (i.e. “the face I make when I feel down”).

For each continuum, the category boundary was determined by using the face that was identified as one emotion (i.e. the anchor) more than 66% of the time. Once the category boundary was determined by the identification task, the discrimination task was conducted to confirm the category memberships. Here, the results were consistent with categorical perception. Adults showed an increase in performance on the discrimination task for pairs of images that spanned the boundary of two categories compared to an equally physically dissimilar pair taken from within a category. The point where the differences between the facial expressions were the most prominent according to the identification task was considered to be the boundary point where the continuum changes from one emotional expression to another. Faces on either side of the boundary were considered to be within a category of a single facial expression. Etcoff and Magee (1992) found that participants were better at differentiating between faces at the boundaries rather than within them for all continua except for those containing surprise as an anchor face. Although these results are important, the stimuli used were low on realism because the line-images lacked pigmentation and surface cues of real faces.

Calder and colleagues (Calder, Young, Perret, Etcoff &Rowland, 1996) conducted a follow-up study using morphed photographic images rather than line images. Images were taken from the Ekman & Friesen (1976) stimuli set which offered photographic-quality expressions. A morphing algorithm was adapted from Benson and Perrett (1991), and it allowed for manipulations to be made to complex and multidimensional stimuli (i.e. coloured photos) in a systematic manner. The algorithm required a large number of facial features points to be placed on each face of the continuum anchors. These points allowed for the positions of the features in one photo to move closer to its position in the other photo. Intermediate faces were created by varying the relative weight of each anchor expression to form new images that were equidistant along a continuum. Calder et al. (1996) found similar results to Etcoff and Magee (1992) providing evidence for categorical perception of facial expression using more naturalistic stimuli. The images used were photo quality depictions of facial emotions performed by actresses rather than line figures. The pictures offered cues including pigmentation and contextual information that make them comparable to real-life observations of faces. In both studies, the adjacent images along the continuum were equally physical differences showing a graduated transformation from one facial expression to the next. If perception of emotional faces is continuous, Etcoff and Magee (1992) and Calder et al. (1996) would not have found a performance advantage at the boundaries because all the faces were equally disparate.

Event-related potential (ERP) and neuroimaging studies have investigated the neuro-underpinnings of categorical perception of facial emotional in adults. In a study using ERPs, the temporal time course of categorical perception along a happy-fear continuum was investigated (Campanella, Quiet, Bruyer, & Crommelinck, 2002). Results showed that the amplitude of the bilateral occipio-temporal negativities (N170) was reduced for within category facial emotional pairs. Additionally, there was a modulation of the P3b wave, such that the amplitude of the responses for between category pairs was higher than for within category pairs. Together, the researchers suggest that it's possible that the neurological origins of categorical perception may be within the occipital-temporal region. Similarly, Rossion, Schiltz, Robaye, Pirenne, and Crommelinck (2001), found using (PET) scans that processing of categorical information (in familiar and unfamiliar faces) occurred in the right occipto-temporal visual pathways.

Categorical perception in infants and children

Although there has been sufficient research to demonstrate categorical perception of facial expressions in adults (Etcoff & Magee, 1992; Calder et al., 1996), research on such categorical perception by infants and children is limited. Understanding the development of categorical perception would shed light on the interplay between constraints on the visual-processing mechanisms and experience, and how this interplay might influence the perception and interpretation of facial expressions. There is some evidence to suggest that mechanisms that allow for categorical perception develop early in childhood For example, infants perceive colour along a continuum categorically (Bornstein, Kessen, & Weisskopf, 1976), as well as speech sounds (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). At the same time, there is strong evidence to suggest that experience influences the phoneme boundaries in the categorical perception of speech sounds (Liberman et al., 1995).

In the seminal work by Kotsoni, de Hann, and Johnson, (2001), two experiments showed evidence of categorical perception of facial emotional expressions in infants, along a continuum of happy to fearful expressions. In this study, photographic images from the Ekman & Friesen (1976) series depicting a 100 % happy (image A) and 100 % fearful (image B) expression were morphed to create a continuum of 6 faces of equal physical distance. In experiment 1, infants were tested on their ability to "identify" faces along the continuum, which serves as a task analogous to the identification task in adults. The study utilized the visual-preference paradigm such that infants' looking time was measured during the presentation of a pair of stimuli consisting of the 100% happy face (image A) paired with one of the five remaining happiness-fear intermediate (blended) faces in the continuum. This method took advantage of infants' known looking preference for fearful over happy faces. Results showed that 7-month-olds looked significantly longer at the fearful face (when compared to the 100% happy face), especially when they crossed the category boundary (i.e. fear faces).

In experiment 2, infants were tested on their ability to "discriminate" faces that were *within* or *between* category boundaries. When tested using a habituation paradigm, infants demonstrated dishabituation to faces across the boundary, only when they were first habituated to a face within the happy category. Dishabituation did not occur when infants were first habituated to faces within the fearful category. Regardless of the mixed results, this study demonstrated that infants by 7 months of age were at least making some category distinctions within a happy-fearful face continuum.

Research using event-related potential (ERP) methodology has investigated categorical perception of facial expressions in the infant brain (Leppanen, Richmond, Vogel-Farley, Moulson, & Nelson, 2009). In this study, researchers demonstrated that ERP measures from 7-month-olds infants were not different *within* categories (in a happy-sad continuum) but reliably differentiated faces *between* categories. Additionally, results showed that face-sensitive ERPs over the occipital-temporal scalp (P400) were attenuated in the within-category condition but not in the between-category condition. Together, the results show evidence of the neural underpinnings of categorical perception of facial emotional expressions along a happy-sad continuum, at least by 7 months of age.

The evidence is stronger with older children. Cheal and Rutherford (2010) found evidence to suggest that at the age of 3.5 years, children perceive emotions categorically along a happy-sad continuum. Using a modified methodology for preschoolers, the study used verbal games to test children's ability to discriminate between two faces from the continuum (i.e., discrimination task), and in a 2-forced choice task whether they could identify the faces as belonging to one category or another (i.e., identification task). Results from the study demonstrated that by the age of 3.5 years, toddlers use categorical perception along a happy-sad continuum, similar to adults.

Finally, there is evidence to suggest that experience influences the development of the categorical perception of facial expressions. In a study of Romanian orphans (Pollack & Kistler, 2002), who were tested on their discrimination and identification abilities along multiple continua, these children were more likely to identify blended faces (i.e. intermediates) as belonging to a negative emotional category than a neutral or positive emotion; there seemed to be a shift in their category boundaries such that there was a bias in labeling emotions as negative, even when they were physically closer to a neutral or positive emotion. The authors argued that early negative experiences with caretakers influenced children to be more cautious in their interpretation of others' emotions, specifically when the emotions are negative (i.e., anger and fear).

Together, the literature suggests that categorical perception of facial emotional expressions develops for some pairs of expressions during the first year of life (Kotoni et al, 2001; Leppanen et al., 2009). Experience and exposure to different emotional expressions seem to have some influence on category boundaries.

Discrimination and labeling of facial emotional expressions

There is evidence to suggest that the perception of faces, especially emotional information, is not the only modality that infants and children use to learn about emotions. Faces and information from faces are privileged from birth and sensitivity to facial emotional information develops through childhood. Yet, infants and children do not learn about emotions via facial expressions alone. Other studies demonstrate that infants and children are also learning about emotions via others' voice pitches (Walker-Andrews & Grolnick, 1983), body language (Boone & Cunningham, 1998), and language (Dunn, Brown, & Beadsall, 1991). By building a repertoire of emotion information across domains, infants and children can build a richer understanding of their own and others emotions. In turn, it is possible that once categorization of emotions occurs, it uses this reservoir of information about each emotion to support within category representations.

Labeling and talking about emotions are important aspects of early parent-child interactions. According to Saarni (1991), the ability to label and discuss experiences with emotions is a central component of emotion understanding and development. Talking about emotions helps children understand, represent, and respond to others' emotions appropriately. For example, parent-child conversations about negative emotions and their consequences enable 24-to 36-month-olds to think casually about their feelings (Lagattuta & Wellman, 2002). Thus, providing labels for emotions, and encouraging their use, may facilitate children's ability to sort emotions into functional categories.

Labeling can also influence perception of objects and faces, at least in adults. In adults, Newell and Bulthoff (2002) found that classifying objects produced increased discriminability for these objects at the category boundaries. Further, categorical perception is more robust when the faces are familiar vs. unfamiliar (in identity), but categorical perception can be influenced by labeling the endpoints (anchors) of the continuum, in this case (Kikutani, Robertson, & Hanley, 2008). It should be noted that these influences are yet unclear in infants and children.

Together, it is clear that both perception of facial emotional information during infancy and labeling of emotions during early childhood influence the development of children's social emotional understanding. Given evidence from the adult literature that labeling faces can influence their perception (along a continuum) or vice versa, it would not be surprising to find a similar relation in children. Yet, these questions have not been explored.

The current research

In three empirical studies, this thesis investigates the developmental trajectory of categorical perception of emotional facial expressions. Chapter 2 is an investigation in categorical perception in infants' aged 6-, 9-, and 12-months along two continua, Happy-Sad and Happy-Angry. This study expands on the current literature by providing developmental data for the first time that includes three different age groups, and across two different continua. It was the first study to examine categorical perception in infants using photo quality coloured images from the NimStim stimuli set. Chapter 3 investigates categorical perception in 26-month-olds along the Happy-Sad continuum using a novel method adapted for testing of toddlers. It allows use of adult-like methods for tests with young children. It fills a gap in the current literature on the development of categorical perception by investigating a previously unstudied age group. Finally, Chapter 4 tests a relationship between sensitivity to the perception of facial emotional expressions (i.e., happy vs. sad faces) and the use of emotion labels in toddlers. Here, we use the number of emotion words used by the toddler (as reported by parents) as a proxy measure of parent-child conversations about emotions (i.e., increased discussions of emotions increases frequency of exposure to emotion words and use of emotion labels). This study is the first to investigate this relation and expands on our current understanding of how emotion understanding is supported by learning across multiple domains.

CHAPTER 2

CATEGORICAL PERCEPTION ALONG THE HAPPY-ANGRY AND HAPPY-SAD CONTINUA IN THE FIEST YEAR OF LIFE

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Preamble

Categorical perception is a psychological phenomenon that enables the perception of physical differences in same category stimuli to be diminished, while *between category* differences to be enhanced, even when the differences are equal (Harnad, 1987). In other words, categorical perception allows superficial differences in *within category* stimuli to be ignored while increasing the saliency of *between category* differences. Once a stimulus has been sorted into discrete categories, inferences can be made about each category that allow for appropriate responses to the stimuli. Categorical perception has been observed across multiple domains including speech sounds (Eimas, Siqueland, Juscyk, Vigorito, 1971), music (Burns & Ward, 1978), and color (Bornstein & Korda, 1984).

Ample evidence demonstrates that categorical perception of facial emotional expressions occurs in adults (Etcoff & Magee, 1992; Calder et al., 1996) yet; research into the developmental trajectory of categorical perception of facial emotional expressions has been limited. In one study, 7-month-olds showed evidence of categorical perception along a happy-fear continuum (Kotsoni, de Hann, & Johnson, 2001), but only when infants were habituated to the happy face first. In this study, the identification and discrimination tasks were modified to better suit the testing of infants. Typically, the identification task requires more than a hundred repetitive trials, which infants would not have the attention span or stamina to complete. Thus, the category boundary for the happy-fear continuum was predetermined for the discrimination task prior to testing. Once the category boundaries were confirmed using the modified identification task, infants were tested on their ability to discriminate *within* and *between* category facial emotional expressions. Other studies have investigated categorical perception using similar methods across different continua including examples from happy-surprise and happy-fear emotion pairs (Ludemann & Nelson, 1988), but again discrimination of faces was in some cases (e.g. happy-fear) dependent on the order of presentation during habituation.

The research into the development of categorical perception is quite limited so several questions remain. For example, does categorical perception develop concurrently for all emotion pairs? Does categorical perception develop with age? In this exploratory study, I investigated categorical perception in 6-, 9-, and 12-month-old infants along a happy-sad continuum and a novel continuum created using happy and angry faces. This study utilized faces from a relatively new stimuli set, NimStim, which provided coloured, photograph quality images. Similar to previous studies (Kotsoni et al, 2001), I modified the identification and discrimination tasks to better suit testing of infants. First, infants were tested for their ability to "identify" *between* category faces that were from across a predetermined category boundary for the happy-sad and happy-angry continua. Results demonstrated that infants at 9-, and 12-month-old infants, but not 6-month-olds, could discriminate faces from across the category boundary for the happy-angry continuum. Infants at 9- and 12-months did not discriminate faces across the category boundary for the happy-sad continuum. In the “discrimination” task, 9- and 12-month-old infants were tested on their ability to discriminate *within* category faces from the “angry” category and from the “happy” category. Results demonstrated that infants from both age groups failed to discriminated faces from within the same category.

Together, results from the modified identification and discrimination tasks were taken as evidence for categorical perception in the happy-angry continuum but not happy-sad continuum. I suggest that categorical perception does not develop uniformly across pairs of emotions and the results suggest that categorical perception may have a long developmental trajectory. Finally, the results suggest that categorical perception may develop as facial emotional expressions become relevant to the child.

Abstract

The current study investigated 6-month-old, 9-month-old and 12-month old infants' ability to categorically perceive facial emotional expressions depicting faces from two continua: Happy-Sad and Happy-Angry. In a between-subject design, infants were tested on their ability to discriminate faces that were between-category (across the category boundary) or within-category (within emotion category). Results suggest that 9- and 12 month-olds can discriminate between but not within categories, for the Happy-Angry continuum. Infants could not discriminate between cross-boundary facial expressions in the Happy-Sad continuum at any age. We suggest a functional account; categorical perception may develop in conjunction with the emotion's relevance to the infant.

Keywords: Categorical perception, emotion perception, faces, categorization

1 Introduction

The ability to perceive and recognize facial expressions is an important aspect of early social development for preverbal infants because facial expressions play a central role in social interactions. In particular, people can infer the thoughts, feelings and intentions of others by observing facial expressions. In turn, this information allows children to begin predicting the behavior of others. This is important because recognizing facial emotional expressions, and understanding the meaning of these expressions, guides the infant's own behaviour. Previous research in this area has mainly focused on infants' ability to discriminate and categorize facial emotional expressions, and categorical perception of emotions will also be the focus of the current experiments.

From birth infants' look preferentially at faces (Maurer, 1985), suggesting that faces are privileged visual objects, attracting infants' attention. Previous research has suggested that the ability to discriminate and categorize facial emotional expressions emerges during infancy, but results have been inconsistent. For example, studies have found that 3-month-olds can discriminate smiling from frowning faces (Barrera & Maurer, 1981), 4-month-olds look longer at happy faces than at angry or neutral faces (LaBarbera, Izard, Vietze, & Parisi, 1976), 5-month-olds smile more at happy than at sad faces (D'Entremont & Muir, 1999; Caron, Caron, & MacLean, 1988), 5-month-olds can categorize smiling faces of various intensities, across individuals, and differentiate them from fear faces (Bornstein & Arterberry, 2003), and 4- to 6- month old infants look longer at angry and surprise faces, rather than at fearful faces (Serrano, Iglesias, & Loeches, 1992). In contrast, other studies have found that 7-months-old infants can only discriminate a happy face from an angry face when accompanied by vocalizations (Caron et al., 1988). Seven-month-old infants could discriminate happy from fearful faces, but only if first habituated to happy faces and not visa versa (Nelson, Morse, & Leavitt, 1979). These divergent findings seem to derive from differences in methodology (Bornstein & Arterberry, 2003), regardless, the general consensus is that infants as young as 6-months of age are capable of discriminating and categorizing positive from negative emotions. Given these divergent findings, however, one of the goals of the current experiment will be to clarify these findings by using more conservative methodology and novel stimuli.

1.2 Categorical Perception

Categorical perception is a perceptual mechanism in which discrete categories are perceived, even though a stimulus set may differ gradually, with no abrupt physical differences across the perceived category boundary. Previous research has demonstrated that categorical perception occurs across domains such as in speech sounds (Liberman, Harris, Hoffman & Griffith, 1957). It is also evident in the perception of basic emotional facial expressions categorically in adults (Calder, Young, Perrett, Etcoff, & Rowland, 1996; Etcoff & Magee, 1992). Categorical perception is functional because it allows for quick identification of stimuli and the formation of appropriate responses in possibly ambiguous situations. Further, categorical perception allows attention to focus towards meaningful differences, rather than meaningless differences, in facial stimuli such as changes in facial features between different emotional expressions. At the same time, differences within a single emotional expression are ignored. This is important because given the vast amount of changes in facial expressions; it would be beneficial for a mechanism that makes identification and classification of important social information efficient.

In a typical categorical perception experiment participants complete two tasks: an identification task and a discrimination task. In the identification task, participants are asked to identify faces as belonging to one category or another. In the discrimination task, participants are asked to make discriminations between and within categories. Higher accuracy across the category boundary than within category is characteristic of categorical perception. When the boundary identified by the identification task can be used to predict maximum discriminablity then perception is said to be categorical.

Evidence for categorical perception of emotional facial expressions in infants and children has been limited. Leppänen, Richmond, Vogel-Farley, Moulson, & Nelson (2009) found that in a visual preference task with happy and sad expressions, infants showed increased looking time to the between category pairings but not to within category pairings. Seven-month-old infants show evidence of categorical perception along the Happy-Fear continuum, but only when habituated to a Happy face rather than to the Fear face (Kotoni, de Haan, & Johnson, 2001). Ludemann and Nelson (1988) used mild and intense versions of Happy, Fear, and Surprise faces, but found that infants' ability to discriminate and categorize depended on the expression shown during habitation. Further work is needed to provide clarification in terms of the developmental trajectory of categorical perception. It is yet unclear whether categorical perception develops concurrently for different basic facial emotions and whether the age is a factor that impacts the emergence of categorical perception.

It is plausible that categorical perception develops at separate ages for different emotions, based on when the expression becomes relevant in guiding an infant's behaviour. For example, an adaptive behavioural response might be required when a fear or angry face is present, so infants might develop perceptual expertise for these negative emotions earlier than, for example, sad or disgusted faces. Specifically, categorical perception might be a mechanism that develops much earlier for threat-related emotions compared to positive emotions. Adaptive behavioural responses to these threat emotions may be important when infants are becoming mobile, since the ability to quickly detect anger or fear within their caregiver's facial expression would be imperative to their safety. Infants are known to use their caregivers facial expressions to guide their own behaviours (e.g. Sorce, Emde, Campos, & Klinnert, 1985).

1.3 The Current Study

The current study was designed to advance our understanding of the development of categorical perception beyond the previous literature. First, the experiments described here use infant-controlled habituation trials a relatively conservative methodology. This will address limitations in previous studies where a lack of dishabituation to a novel expression could be attributed to insuffient opportunities for encoding the stimulus. Second, the current experiment will use a closed mouthed model from the novel stimuli set (e.g. NimStim) and use digital morphing technology to systematically create equally spaced intermediates to form a continuum. Finally, 6-month-old, 9-month-old, and 12-month-old infants will be tested on their ability to discriminate facial emotional expressions across boundaries and within categories, for a Happy-Sad or a Happy-Angry continuum.

In Experiment 1, infants will be tested on whether they dishabituated to, and thus discriminate, facial expressions across a category boundary. In Experiment 2, infants will be tested on whether they dishabituate to faces within the same category. In a between-subjects design, Experiment 1 will include both a Happy-Sad and a Happy-Angry continuum conditions, so a comparison can be made across ages and facial emotions. Experiment 2, as a contrast condition to Experiment 1, only included faces within the Happy and Angry categories.

2. Experiment 1: Between Category Boundaries

2.1 Materials and Methods

2.1.1 Participants

Healthy full-term 6-, 9-, and 12-months old infants participated in this study. Forty-three 12-month-olds participated, 22 in the Happy-Angry Continuum Condition (11 males; mean age 12 months, 0 days, range 11:14-12:24) and 21 in the Happy-Sad Continuum Condition (11 males; mean age 12 months, 6 days, range 11:24-12:21). Forty-one 9-month-olds participated, 21 in the Happy-Angry Continuum Condition (11 males; mean age 9 months, 8 days; range 8:18-9:24) and 19 in the Happy-Sad Continuum (9 males; mean age 9 months, 0 days; range 8:20-9:16). Six-month-olds (n=23) only participated in the Happy-Angry Continuum

Condition (14 males; mean age 6 months, 7 days; range 5:18-6:26)[1]. Ten additional 6-month-olds, 17 9-month-olds, and 17 12-month-olds participated but were excluded from analyses because of fussiness (17), no habituation (20), or parental interference (7).

Infants were recruited from a database created from parents approached during hospital visits. Participants lived within a mid-sized city and the surrounding regions. They received a token gift for their participation.

2.1.2 Stimuli

Stimuli in this experiment consisted of 4 coloured photographs from the NimStim Face Stimulus Set (Tottenham, et al, 2009, Model 7) from a morphed continuum anchored by a Happy Face and an Angry Face (See Figure 1, Happy-Angry Continuum) or a Sad Face (See Figure 2, Happy-Sad Continuum).

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[1] Testing for the Happy-Sad continuum occurred first for the 9- and 12-month-olds infants. Infants in both these age groups were unable to discriminate faces between the category boundary, so to preserve resources 6-month-olds were not tested in this condition.

Figure 1.

Figure 1. Happy-Angry Continum. Experiment 1 used Image 2 and Image 3 as the between Happy-Angry category boundary faces. Experiment 2 used Image 1 and Image 2 as the within Happy Category faces, and Image 3 and Image 4 as the within Angry Category faces.

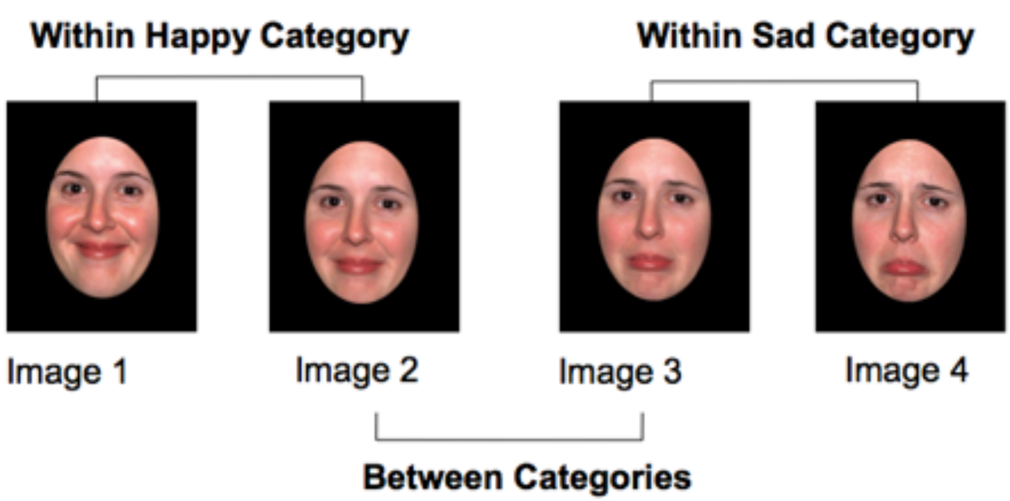

Figure 2. Happy-Sad Continum. Experiment 1 used Image 2 and Image 3 as the between Happy-Sad category boundary faces. Experiment 2 used Image 1 and Image 2 as the within Happy Category faces, and Image 3 and Image 4 as the within Sad Category faces.

The morphed continua were created using Morpheus v1.85 software. This program requires the user to supply matching locations on two images. Using these fixed points, the program interpolates at the desired interval (in our study 33%)[2] to create intermediate images. The resulting continuum included two intermediate images (33% Happy and 66% Happy, Figure 1, Image 2 and Image 3; Figure 2, Image 3 and Image 3) and two endpoint (100% sad or 100% Happy) images for a total of four images per continuum. The morphed images were altered using Adobe Photoshop 7.0 to remove hairline and outer contour of the faces (faces were encircled within a black background) in order to make all images consistent.

2.1.3 Procedure

Infants' were positioned 90 cm from a TV monitor (49.80 cm by 88.3 cm) that displayed the stimuli. The 6- and 9-month-old infants were seated in their parents lap, whereas the 12-month-old infants were seated in the same position but in a highchair. Parents were told to look down and to keep their expression neutral for the duration of the experiment.

A Macbook Pro laptop was used to run the software Looking Time X (Hannigan, 2008), which controlled the presentation of the pictures. When presented on the computer monitor, facial expressions were similar in size to an

[2] This interval was used based on pilot data collected using a separate group of 9-month-old infants. In this pilot work, a 20% interval was used to create the intermediate face exemplars because it reflected the typical boundary distance between categories for adults along a Happy-Sad continuum. But infants failed to discriminate faces between across the boundary of two emotion categories, so it was decided that the interval should be widened to 33%.

adult face (10 cm by 15 cm). Soft neutral music was played in the background for the duration of the study to prevent fatigue and to mask external noise.

During habituation trials, infants were shown a static face depicting an emotion. A movie clip with a 10s display of the emotion followed by a 0.5s blank black screen was played on a loop until the infant looked away from the computer monitor for 2 consecutive seconds or if 120s had elapsed. Habituation criterion was defined as three consecutive trials with a summed looking time of less than or equal to 50% of the sum of the looking time on the first 3 trials. Infants were presented with a minimum of 6 and a maximum of 14 habituation trials, which is standard for looking-time paradigms (Woodward, 1998).

In order to test whether infants could detect a difference *across* the category boundary (Image 2 and Image 3, for each continuum), we presented infants with two test movies, one at a time of (1) a face depicting the same emotion seen during habitation and (2) a novel emotion (from the other side of the category boundary along the same continuum). Infants watched the two test trial types in alternation for a total of 4 trials. If infants were sensitive to differences in facial expressions between categories, just like adults, then those who habituated to one emotion (here after called: “old emotion”) should look longer at a movie depicting the “novel emotion” (from across the boundary of the continuum). In contrast, if infants cannot detect differences in facial expressions across boundaries there should be no significant difference in looking time. The order in which the facial emotions were presented was counterbalanced between infants within each condition.

Infants' attention toward trials during the habituation and test phase was coded online by two trained coders (1 primary coder who controlled stimuli presentation by button press and a second independent coder) who were unaware of the testing order and could not see any of the test events. The software Baby (Barrett and Baillargeon, 2004) was used to calculate the looking times. Data were considered reliable if the inter-rater reliability was 90% or above on all trials.

2.2 Results and Discussion

2.2.1 Habituation.

Infants in the Happy-Angry Continuum Condition habituated in an average of 7.7 trials (SE=0.26). The mean looking time on the first three trials was 15.29s (SD=1.3), and decreased to a mean of 4.88s (SD=0.37) on the last three trials. The rate of habituation did not differ between the age groups (6-month-olds habituated in 7.13 trials, 9-month-olds habituated in 8.27 trials, and 12-month-olds habituated in 7.9 trials, $F(2,64)=1.73$, $p=0.18$). Infants in the Happy-Sad Continuum Condition habituated in an average of 7.5 trials (SE=0.33). The mean looking time on the first three trials was 13.95s (SE=1.89), and decreased to a mean of 4.14s (SE=0.38) on the last three trials. The rate of habituation did not differ between the age groups (9-month-olds habituated in 7.8 trials, and 12-month-olds habituated in 7.2 trials, $t(19)= 0.801$, $p = 0.33$).

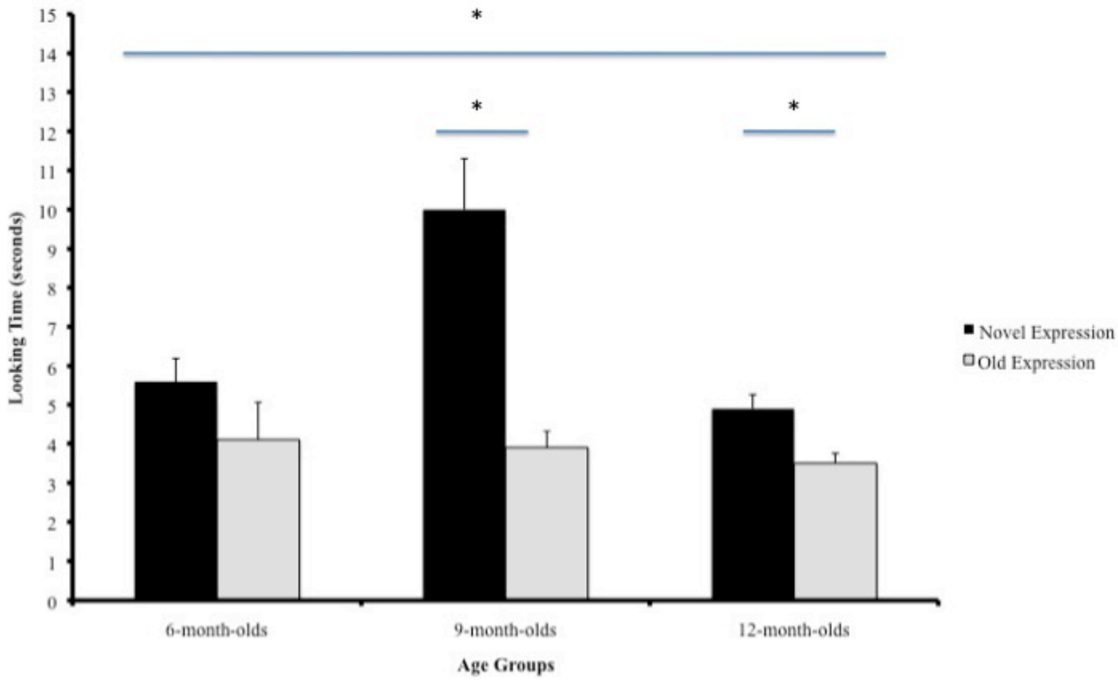

Figure 3. Looking time (with standard error bars) to facial emotional expressions (coded as "Novel" or 'Old") across the category boundary along the Happy-Angry continuum for the first-pair of test trials, for each age group. An asterisk (*) denotes significance at $p < 0.05$.

2.2.2 Test Events. The main focus of Experiment 1 was to investigate whether infants at 6-, 9-, and 12-months could differentiate two facial expressions that crossed category boundaries. When habituated to a facial expression from one side of the boundary would infants look longer when presented with a novel facial expression from across the category boundary? To test this question, analyses were conducted on infants' average looking times to the two types of test trials (i.e. novel vs. old emotional facial expression) across the 4 test trials. Preliminary analysis of variance on looking time revealed no main effects of gender, facial emotion shown during habituation (Happy, Angry, or Sad) or test trial order and no significant interactions between these variables. Therefore, the subsequent analyses were collapsed across these dimensions.

Previous research suggests that younger infants and older infants' looking times often differ in studies using habituation, therefore we analyzed the data for the 6-, 9-, and 12-month-olds separately (Philips et al, 2002, Kuhlmeier et al, 2003). For 12-month-olds in Experiment 1, a repeated measures ANOVA on infants' looking times in test demonstrated a significant Trial Type (Old Emotion vs. Novel Emotion) x Condition (Happy-Angry vs. Happy- Sad) interaction ($F(1, 41) = 4.56$, $p = 0.04$). Planned contrasts (two-tailed) found that twelve-month-olds infants in the Happy-Angry Continuum Condition looked significantly longer on average cross all test trials at the Novel Emotion (4.2s, SE=0.37) than the Old Emotion (3.1, SE=0.25), $t(21)= 3.38$, $p = 0.003$, two-tailed (See Figure 3). In contrast, infants in the Happy-Sad Continuum Condition had no preference (mean look to Old Emotion = 5.9, SE= 0.94; Novel Emotion = 5.3, SE= 1.4, $t(21) = 0.53$, $p = 0.62$. Non-parametric analysis also revealed that 15 out of 21 infants in the Happy-Angry Continuum Condition looked longer at Novel Emotion (binominal test, $p = 0.02$, two-tailed) than the Old Emotion, whereas only 12 of 21 infants looked longer at the Novel Emotion than the Old Emotion in the Happy-Sad Continuum Condition ($p = 0.14$, two-tailed).

For the 9-month-olds a repeated measure ANOVA revealed a marginally significant main effect of Trial Type ($F(1, 39)= 3.43$, $p = 0.07$), a significant Trial Type x Condition interaction ($F(1,39)= 5.20$, $p = 0.02$), and a significant Trial Type x Condition x Pair (1st Pair of test trials vs. 2nd Pair) interaction ($F(1, 39)= 5.24$, $p = 0.02$). Further analysis revealed that 9-month-olds in the Happy-Angry Continuum Condition looked significantly longer at the Novel Emotion (10.0s, SE= 2.3) than the Old Emotion (3.9s, SE=0.42), $t(21)= 2.60$, $p =0.02$) primary on the first pair of test trials, which accounted mostly for the significant interactions indicated above (See Figure 3). The looking time differences were not significant in the second pair of test trials ($p = 0.5$). Finally, there were no significant differences between looking time towards the Novel Emotion and the Old Emotion by infants in the Happy-Sad Continuum Condition on any pair of the test trials, all $t(18)=0.27$, $p = 0.78$). The pattern of looking in the first pair of test trials revealed that 17 of 22 infants in the Happy-Angry Continuum Condition looked longer at the Novel Emotion vs. the Old Emotion ($p=0.006$), whereas 8 of 19 infants in the Happy-Sad Continuum Condition did the same ($p = 0.14$).

Six-month-olds, who only participated in the Happy-Angry Continuum Condition, revealed no preference in looking time towards either the Novel (5.6s, SE= 0.59) or Old Emotions (4.1, SE= 0.97) on the first test pair ($t(22)=1.48$, $p = 0.15$, two-tailed), see Figure 3, or across all test pairs (Novel Emotion: 5.0s, SE= 0.53, Old Emotion, 4.3s, SE= 0.40, $t(22)=1.69$, $p = 0.10$, two-tailed). Fourteen of the 23 infants looked longer at the Novel Emotion over the Old Emotion across all test trials, which was no significant (p = 0.10, two-tailed).

In sum, results from Experiment 1 indicate that infants at 12- and 9-months, but not 6-months, are capable of distinguishing between the facial expressions of emotions that are equally physical different *across* the boundary within a Happy-Angry continuum. Nine- and 12-month-old infants were unable to discriminate faces across the category boundaries for the Happy-Sad continuum. Twelve-month-olds were able to differentiate between the Happy and Angry faces across all test pairs, whereas 9-month-olds showed the strongest effect in the first test pair. The hallmarks of categorical perception is the ability to quickly and accurately differentiate between facial emotions between category boundaries, but also the inability to do so when the facial emotions occur *within* categories. The next experiment will address this prediction.

3. Experiment 2: Within Category Boundaries

Categorical perception of facial emotional expressions involves the ability to accurately and efficiently discriminate emotions across category boundaries, but discrimination diminishes within categories. In fact, most adults will group together expressions at the extremes of the continua (Figure 1, Image 1 and Image 2 or Image 3 and Image 4) and label them as perceptually similar (Cheal and Rutherford, 2011). In Experiment 1, we demonstrated that 9- and 12-month-old infants could differentiate between facial emotional expressions across the category boundaries along the Happy-Angry Continuum. Here, we tested 9-month-old infants' on whether they were sensitive to differences in facial emotional expressions *within* the category boundary and closer to the extremes of the continua. If infants are relying on a mechanism like categorical perception to identify facial expressions, then 9-month-olds should fail to differentiate between the old and novel facial expressions as adults do. Here, we presented infants with facial emotional expressions from within the Happy Category Boundary (Figure 1, Image 1 and Image 2) and Angry Category Boundary (Figure 1, Image 3 and Image 4).

3.1 Materials and Methods

3.1.1 Participants

Sixteen 12-month-olds participated, 8 in the Within Happy Category (3 males; mean age 12 months, 19 days; range 11:25-12:27) and 8 in the Within Angry Category (3 males; mean age 12 months, 13 days; range 11:15-12:24). Seventeen additional infants were tested but were excluded from analysis because they did not reach habituation criterion (n=7), parental or sibling interference (n=5), and due to experimental error (n=5). Thirty-eight 9-month-olds participated, 19 in the Within Happy Category Condition (11 males; mean age 9 months, 1 days; range 8:20-9:27) and 19 in the Within Angry Category Condition (9 males; mean age 9 months, 15 days; range 8:04-9:29). Five additional infants were tested but were excluded from analysis because they did not reach the habituation criterion (n=3), parental interference (n=1), and because they became irritated during the experiment (n=1). Participants were recruited in the same manner and geographic area as in Experiment 1. All participants received a token gift for their participation.

3.1.2 Stimuli and Procedure

The stimuli and procedure were identical to those used in Experiment 1 with the key difference being the use of faces within the Happy category (Figure 1, Images 1 and 2) or within the Angry category (Figure 1, Image 2 and 3) during habituation and test, rather than faces between the categories.

3.2 Results and Discussion

Preliminary analysis of variance on looking time revealed no main effects of gender, facial expression shown during habituation or test trial order, and no significant interactions between these variables. Therefore, the subsequent analyses were collapsed across these dimensions.

3.2.1 Habituation.

Infants in the Happy Category Condition habituated in an average of 7.75 (SE = 2,1) trials for the 12-month-olds and 7.05 trials (SE = 2.0) for the 9-month-olds. The mean looking time on the first three trials was **11.07s (SE = 7.6)** for the 12-month-olds and 18.6s (SE = 2.2) for the 9-month olds, decreased to a mean of 11.03 (SE= 3.1) for the 12-month-olds and 5.82s (SE=0.64) for the 9-month-olds on the last three trials.

Infants in the Angry Category Condition habituated in an average of 7.3 trials (SE= 1.7) for the 12-month-olds and 8.0 trials (SE = 0.51) for the 9-month-olds. The mean looking time on the first three trials was 18.0s (SE= 11.5) for the 12-month-olds and 15.1s (SE = 2.4) for the 9-month-olds, then decreased to a mean of 7.3s

(SE= 4.7) for the 12-month-olds and 4.74s (SE=0.63) for the 9-month-olds on the last three trials. There were no significant differences in the number of trials to habituation (12-months; $F(1,15) = 0.14$, $p = 0.71$, 9-months; $F(1, 36) = 1.81$, $p = 0.18$ or the overall looking-time during habituation between the two conditions (12-months; $F(1,14) = 2.17$, $p = 0.16$, 9-months; $F(1, 36) = 1.26$, $p = 0.26$) for the 12-month and 9-month-olds respectively

3.2.2 Test Trials.

The main focus of Experiment 2 was to investigate whether infants could differentiate two facial expressions *within* the happy category or *within* the angry category along the Happy-Angry continuum. Here, we are testing whether infants look longer when presented with a new facial expression (i.e. Novel Emotion) having been habituated to another facial emotional expression (Old Emotion) even though both emotions are within the same category. Importantly, the interval or difference between the facial expressions was the same as the two facial expressions, which were between category boundaries as shown in Experiment 1. This allowed us to rule out and control for physical differences between the facial expressions of the emotions, since all facial emotional expressions were created with equal intervals. To test this question, the analyses were conducted on infants' average looking to the two types of test trials (i.e. novel vs. old emotion).

Twelve-month-olds in both conditions did not preferentially look longer at either the Novel Emotion or Old Emotion on the first pair of test trials (Happy

Category; t(7)=1.5, p = 0.15, Angry Category; t(7)= 0.49, p = 0.63 or overall (Happy Category; t(7)= 1.4, p = 0.19; Angry Category; t(7)= 0.15, p = 0.88).

Since an effect of looking-time was strongest in the first pair of test trials for 9-month-olds in Experiment 1, we will only be reporting on first pair results here. Nine-month-olds in neither conditions preferentially looked at either the Novel Emotion or the Old Emotion on the first pair of test trials or overall (Happy Category; t(18)= 0.88, p = 0.38, Angry Category; t(18)= 0.76, p = 0.86). Eight of 19 infants looked longer at the Novel Emotion in the Happy Category condition (p = 0.14) and 7 of 19 looked longer at the Novel Emotion in the Angry Category (p = 0.82).

A repeated measures ANOVA was conducted to compare looking-time differences to the Novel and Old Emotions between 9-month-olds in Experiment 1 to infants in both conditions in Experiment 2. Results revealed a significant Trial Type x Experiment interaction ($F(1, 57)= 3.32$, p = 0.04), such that 9-month-olds in Experiment 1 looked longer at the Novel Emotion than the infants in both conditions of Experiment 2.

4. General Discussion

The present study was designed to characterize the development of categorical perception of facial emotional expressions along a Happy-Angry and Happy-Sad continuum in the first year of life. We were interested in whether an infant-controlled habituation paradigm would allow infants the opportunity to encode negative facial emotional information, the age at which evidence of categorical perception emerges for these continua and whether evidence of categorical perception emerges in one continuum before the other. Together, this would clarify components of the developmental timing of categorical perception of facial emotional expressions.

For the Happy-Angry continuum, 9- and 12-month-olds were able to discriminate between a pair of faces that spanned the category boundary. When tested using facial emotional expressions within the category boundaries, 9- and 12-month old infants were unable to discriminate the equally physically distinct pair of faces within the Happy and Angry category. Taken together, this pattern of results suggest that using a habituation paradigm and using stimuli from a new continuum created from the NimStim Set of facial emotional expressions, infants at 9- and 12-months were capable of categorical perception along the Happy-Angry continuum. In contrast, using the same paradigm, 6-month-old infants showed no evidence of discriminating faces that spanned the Happy-Angry category boundary. In other words, they showed no evidence of categorical perception for this set of emotional expressions.

For the Happy-Sad continuum, 9- and 12-month-old infants were tested for their ability to discriminate facial emotional expressions across the category boundary with Happy and Sad faces. Our findings yield no evidence that either age groups could discriminate face pairs that spanned the Happy-Sad category boundary. Therefore, 6-month olds were not tested in this condition. Here, the inability to discriminate between faces that spanned the category boundary suggests that 9- and 12-month olds would fail to pass the test of discrimination required to claim categorical perception along the Happy-Sad continuum in this particular paradigm. Yet, it should be noted that the inability to discriminate cross-boundary pairs in our Happy-Sad continuum does not unequivocally demonstrate an inability to categorically perceive facial emotional expressions. It is plausible that these results are a function of the stimuli presented in our study. For example, if shown faces along a continuum created from anchor faces that depicted more exaggerated versions of the Happy and Sad expressions, infants might demonstrate categorical perception. This same logic applies to the results from the 6-month-old olds in the Happy-Angry between-category conditions, such that the inability to discriminate is not evidence against categorical perception. Although these speculations are beyond the scope of this paper, it suggests the need for further investigation using a more facially intense stimuli set.

Another possible developmental account for infants' categorical perception across the Happy-Angry but not the Happy-Sad continuum involves the visual information associated with changes across the category boundaries for each continuum. Previous work by Gao and Maurer (2010), suggest that various emotional expressions include varying amounts of psychophysical information depending on the intensity of the facial expression. The physical changes in facial features across some emotions are physically more similar than others. Infants' in the current study have an inability to discriminate between faces across the category boundary in the Happy-Sad continuum, which could be a function of the physical similarity between cross boundary pairs.

Thus, the ability to discriminate cross-boundary pairs in the Happy-Angry continuum could be attributed to the dissimilarity between the faces at the boundary points. Follow-up studies using a continuum of faces created from more exaggerated versions of facial emotional expressions as anchors, in which physical differences are equated across continua, might test more directly an infant's categorical perception of emotional expressions. Note, however, that anchor faces used to create the continua in the current study would more closely resemble naturally occurring expressions in an infants' social environment. Although it could be argued that infants encounter a high frequency of exaggerated expressions, it seems likely that most natural facial expressions are not extreme. Thus, our pattern of discrimination (or inability to discriminate) cross boundary pairs might reflect categorical perception as it occurs in the infant's environment.

Additionally, the fixed interval (physical difference) between our intermediate faces was 33%, an interval that is larger than typically used when testing for categorical perception in adults. As noted in the methods section, pilot data collected from 9-month-old infants tested from a continuum created from another model's face and using 20% intervals yielded null results. Therefore, the difference was widened to 33%. Although we widened the interval between faces, however, this did not change the exaggeration of the anchor faces.

Results from the present study suggest some differences in developmental timing across continua, and these differences may be related to the functional relevance of a particular facial emotion. The pattern of results across Experiment 1 and Experiment 2, suggest differences in sensitivity to faces along the Happy-Angry and Happy-Sad continua because of the ability to discriminate between category pairs in the Happy-Angry, but not Happy-Sad, continuum. Adaptive behavioural responses to threat cues such as an angry or fearful facial expression is biologically important, even to a young infant, so, the perception of these stimuli should develop early. In contrast, infants may not be capable of generating a functional behavioural response to facial emotional expressions of sadness in adults, so the categorical perception across a Happy-Sad continuum may not be beneficial until later in development. For example, when the capacity to engage and act on empathic feelings emerges. It should be noted, however, that this argument doesn't negate the possibility that exposure and experience with specific facial emotional expressions within the environment may also be driving the development of categorical perception. Previous research has indicated that exposure and frequency of different facial expression in the environment can skew the perception and categorization of emotions along a continuum (Pollack & Kistler, 2002).

The use of only one actress in the stimuli set may limit the ability to generalize the results. Typically, studies looking infants' ability to discriminate and categorize facial emotional expressions use multiple models to control for the possibility that infants' use of changes in the physical features of a face rather than an emotion, in discrimination tasks. However, previous studies using only one actress and multiple actresses as exemplars typically share similar findings (Bornstein & Arterberry, 2003) therefore, although it limits our findings it does not completely negate them.

Our experiments used only one of the two tasks traditionally used to test categorical perception, because we were working with a pre-verbal infant population. For this reason, this study does not constitute the strong evidence of categorical perception that is usually expected in studies with adult observers: the agreement in the placement of the category boundary across a discrimination task and an identity-labeling task. In Experiment 1, 9-, and 12-month-old infants' were capable of discriminating faces that span a category boundary. Typically, category boundaries are determined by an identification task. Here, the category boundaries used were those that would closely resemble that of an adult boundary, for both the Happy-Angry and Happy-Sad continua.

Overall, these findings are consistent with previous research using looking-time paradigms to study categorical perception (Kotsoni et al, 2001; Bornstein & Arterberry, 2003; Kotsoni et al., 2001). Our results demonstrate that infants in the first year of life are capable of differentiating faces across category boundaries along a Happy-Angry continuum but not a Happy-Sad continuum. Both 9- and 12--month-olds were unable to discriminate faces within category boundaries in the Happy-Angry continuum. Although further research is needed to fully encapsulate the developmental timing of categorical perception across different facial emotional expressions, we suggest that differences may be related to the functional relevance of each expression to an infant.

Acknowledgements

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Reference List

Barrera, M. E. & Maurer, D. (1981). The perception of facial expressions by the three-month-old. *Child Development, 52,* 203-206.

Bornstein, M.H. & Arterberry, M.E. (2003). Recognition, discrimination, and categorization of smiling by 5-month-old infants. *Developmental Science, 6(5),* 585-599.

Bornstein, M. H., Kessen, W., & Weisskopf, S. (1976). Color vision and hue categorization in young infants.Journal of Experimental Psychology: Human Perception and Performance, 1, 115–129.

Calder, A. J., Young, A.W., Perrett, D.I., Etcoff, N.F., & Rowland (1996). Categorical perception of morphed facial expressions. *Visual Cognition*, *3*(2), 81- 117.

Campanella, S., Chrysochoos, A., & Bruyer, R. (2001). Categorical perception of facial gender information: Behavioural evidence and the face-space metaphor. *Visual Cognition, 8,* 873-882.

Caron, A. J., Caron, R. F., & MacLean, D. J. (1988). Infant discrimination of naturalistic emotional expressions: the role of face and voice. *Child Development, 59,* 604-616.

Cheal, J. L., & Rutherford, M. D. (2011). Categorical perception of emotional facial expressions in preschoolers. *Journal of Experimental Child Psychology, 110*, 434–443.

D'Entremont, B. & Muir, D. (1999). Infant responses to adult happy and sad vocal and facial expressions during face-to-face interactions. *Infant Behaviour & Development, 22,* 527-539.

de Haan M, and Nelson CA. (1998). Discrimination and categorization of facial expressions of emotion during infancy. In: Slater AM, editor. Perceptual development: visual, auditory, and language perception in infancy. London: University College London Press; 1998. pp. 287–309.

Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigorito, J. (1971). Speech perception in infants. *Science, 171,* 303-306.

Etcoff, N.L. & Magee, J.J. (1992). Categorical perception of facial expressions.*Cognition, 44*, 227-240.

Gao, X., and Maurer, D. (2010). A happy story: Developmental changes in children's sensitivity to facial expressions of varying intensities. *Journal of Experimental Child Psychology, 107(2)*, 67-86.

Grossmann, T., Striano, T., Friederici, A.D. (2007). Developmental changes in infants' processing of happy and angry facial expressions: A neurobehavioral study. *Brain and Cognition, 64,* 30-41

Kotsoni, E., de Haan, M., Johnson, M.H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception, 30*, 1115-1125.

Kuhlmeier, V., Wynn, K., and Bloom, P. (2003). Attribution of Dispositional States by 12-month-olds. *Psychological Science, 14*, 402-408.

LaBarbera, J. D., Izard, C. E., Vietze, P., & Parisi, S. A. (1976). Four- and six-month-old infants' visual response to joy, anger and neutral expressions. *Child Development, 47,* 535-538.

Liberman, A.M., Harris, K.S., Eimas, P., Lisker, L., & Bastian, J. (1961). An effect of learning on speech perception: The discrimination of durations of silence with and without phonemic significance. *Language and Speech, 4,* 175-195.

Leppänen, J.M., Richmond, J., Vogel-Farley, V.K. Moulson, M.C., & Nelson, C.A. (2009). Categorical representation of facial expressions in the infant brain. *Infancy, 14,* 346-362.

Levin, D. T. & Angelone, B. L. (2002). Categorical perception of race. *Perception, 31,* 567-578.

Ludemann, P.A. and Nelson, C.A. (1988). Categorical Representation of Facial Expressions by 7-month-old infants. *Developmental Psychology, 24(4),* 492-501.

Maurer, D. (1985). Infants' perception of facedness. In T.Field & N. Fox (Eds.), *Social Perception in Infancy* (pp. 73-100). Norwood, New Jersey: Ablex.

Nelson, C. A., Morse, P. A., & Leavitt, L. A. (1979). Recognition of facial expressions by seven-month-old infants. *Child Development, 50,* 1242.

Phillips, A.T., Wellman, H.M., Spelke, E.S. (2002). Infants' ability to connect gaze and emotional expression to intentional actions. *Cognition, 85,* 53-78

Pollack, S.D. & Kistler, D.J. (2002). Early experience is associated with the development of categorical representations for facial expressions of emotion. *Proceedings of the National Academy of Science of The United States of America, 99*(13), 9072-9076.

Raskin, L. A., Maital, S., & Bornstein, M. H. (1983). Perceptual categorization of color: A life-span study. *Psychological Research, 45,* 135-145.

Serrano, J. M., Iglesias, J., & Loeches, A. (1992). Visual discrimination and recognition of facial expressions of anger, fear, and surprise in 4- to 6-month-old infants. *Developmental Psychobiology, 25,* 411-425.

Sorce, J. F., Emde, R. N., Campos, J., & Klinnert, M. D. (1985). Maternal emotional signalling: Its effect on the visual cliff behaviour of 1-year-olds. *Developmental Psychology, 21*, 195–200.

Tottenham, N., Tanak, J.W., Leon, A.C., McCarry, T., Nurse, M., Hare, T.A. et al. (2009). The NimStim set of facial expressions: Judgements from untrained research participants. *Psychiatry Research, 168*, 242-249.

Vaish, A., Grossman, T., and Woodward, A. (2008). Not All Emotions Are Created Equal: The Negativity Bias in Social-Emotional Development. *Psychology Bulletin, 134 (3),* 383-403

Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*(1), 1-34.

CHAPTER 3

TODDLERS PERCEIVE FACIAL EMOTIONAL EXPRESSIONS CATEGORICALLY ALONG A HAPPY-SAD CONTINUUM

This chapter has been submitted to the journal of *Infant Behavior and Development* for publication. As of the submission of this thesis, this chapter is under review. Copyrights agreements will be obtained from the publisher and transferred to McMaster University, and the Library Archives Canada once the article has been accepted for publication by the journal.

Preamble

Adults perceive emotional facial expressions categorically (Etcoff & Magee, 1992; Calder, Young, Perrett, Etcoff, & Rowland, 1996). In categorical perception, individuals perceive facial emotional expressions in discrete categories, even when the stimulus is presented as continuous. Generally, members of the same category are perceived to be more similar than members from different categories. The perception of superficial differences between same category members is muted, whereas differences in between category members are enhanced, even when the images are the same physical difference apart (Repp, 1984).

Typically, the study of categorical perception in adults involves the use of two tasks: a discrimination task and an identification task. The discrimination task tests an individual's ability to discriminate pairs of stimuli from within or between the category boundaries, as set by the identification task. In the discrimination task, participants are tested on their ability to make perceptual judgments on facial emotional expression from within or between categories. For example, participants are presented with two images (Image A and Image B) from a continuum and are then asked to determined whether a third image (Image X) from the continuum is more similar to Image A or Image B.

In the identification task, participants are asked to label randomly presented stimuli from a continuum. Individuals are provided with two labels representing the anchor stimuli from the end points of the continuum in a 2-alternative-forced-choice experimental design (Etcoff & Magee, 1992). Other studies allow participants to respond with their own words, which are coded later (Calder et al., 1996). The identification task determines the category boundaries for a continuum; with identification of the stimulus switching (e.g. more accurate) from one category to another across the category boundaries.

Together, the results from the identification task and discrimination tasks are used to infer whether there is evidence of categorical perception along a continuum (Harnad, 1987; Repp, 1984; Studdert-Kennedy, Liberman, Harris, & Cooper, 1970). Participants must be better (e.g. faster reaction time, more accurate) at discriminating faces that cross the category boundary, than faces that are within the same category.

Research exploring categorical perception of facial emotional expressions in infants and toddlers has used modified methods in the identification and discrimination tasks. For example, in adults, the identification task helps determine the category boundaries that are confirmed using the discrimination task. But, the identification task typically requires multiple trials, which infants and children do not have the attention span to perform. Rather, the identification tasks is often modified for infants and children such that a best estimate (using adult data) of the category boundaries are predetermined. The identification task then serves to confirm the category boundaries. Additionally, the measure of identification in infants is often dependent on looking-time differences

(Kotsoni et al. 2001), rather than forced-choice paradigm as used in older children (Cheal & Rutherford, 2011) and adults (Etcoff & Magee, 1992; Calder et al, 1996).

Given the relative complexity of adapting measures of categorical perception in infants and children, there is a considerable age gap in the developmental literature. For example, studies of categorical perception of facial emotional expressions typically test infants before 12-months (Kotsoni et al, 2001) or after 3.5 years (Cheal & Rutherford, 2011). In the current study, we used modified identification and discrimination tasks for an age group that had previous not been tested before; toddlers at 26-months. Specifically, we explored their ability to categorically perceived facial emotional expressions along a happy-sad continuum. Our findings suggest that our modified tasks work well with toddlers. This was the first study to demonstrate categorical perception in toddlers. Future studies can utilize this paradigm to study categorical perception in other emotion pairs with toddlers.

Abstract

Adults can perceive a continuum of emotional facial expressions categorically. Categorical perception informs inferences that can guide behavior. A recent study suggests that 12-month-olds were unable to discriminate happy-sad faces across the category boundary (Lee, Cheal, and Rutherford, 2015) although toddlers at 3.5 years of age use categorical perception along the happy-sad continuum (Cheal and Rutherford, 2011). The current study used a novel paradigm that employed a looking time discrimination task and a pointing identification task to test for categorical perception along a happy-sad continuum in younger toddlers at 26-month of age. Results support that categorical perception of the happy-sad continuum may develop earlier than previously tested. We argue that categorical perception for each emotion continuum may develop when an emotion becomes relevant to the child.

1. Introduction

The perception of facial expressions allows for the understanding of another's emotional state, thoughts, intentions, and desires and helps to inform the observer's behavioral response. Basic facial emotional expressions are universal and include happiness, sadness, fear, anger, disgust and surprise (Ekman & Friesen, 1976). These facial expressions are recognizable to adults across cultures, and this recognition and categorization is thought to be adaptive (Darwin, 1872; Etcoff & Magee, 1992).

The perception, recognition, and rapid categorization of facial expressions are crucial in successfully navigating social interactions, enable people to make inferences about novel situations, and inform social decisions. The quick and efficient categorizing of facial expressions into discrete emotions allows for a fast interpretation of the social situation, and guides behavioral decisions. These mechanisms may develop early in infancy and childhood, and studies have previously focused mainly on the development of the perception of emotional facial expressions from infancy (Ludemann & Nelson, 1988; Swartz, Izard, & Ansul, 1985). Here, the study tests for evidence of categorical perception in toddlers, and specifically whether 26-month-olds perceive a continuum from happy to sad faces categorically.

1.1 Adult Categorical Perception of Facial Emotional Expressions

Empirical demonstrations of categorical perception involve continuous stimuli being perceived as discrete categories, and members within one category appearing more similar than members from another category, despite being equally different physically (Harnad, 1987). For example, although colours belong to a continuous gradient of physically shortening wavelengths, individuals perceive a continuum of wavelengths as discrete categories. Additionally, individuals can better discriminate stimuli that span category boundaries, compared to stimuli that fall within the same category, and this discrimination is considered a hallmark of categorical perception. Given these criteria, evidence of categorical perception has been demonstrated in many modalities including speech sounds (Liberman, Harris, Hoffman & Griffith, 1957), colour perception (Bornstein, Kessen, & Weiskopf, 1976), and music perception (Siegel & Siegel, 1977).

Adults perceive facial expressions categorically (Calder, Young, Perrett, Etcoff, & Rowland, 1996; de Gelder, Teunisse & Benson, 1997, Etcoff & Magee, 1992). With adult observers, evidence of categorical perception of emotional expressions typically relies on the convergent results from the two tasks, an identification task and a discrimination task (Harnad, 1987). In the identification task, observers are presented with single faces from a continuum, and are required to label it as one of the two emotions that anchor the endpoints of the continuum. The location on the continuum where a shift in identification occurs is thought to be the category boundary. The discrimination task, can have one of several procedures. One example most relevant to the current study, adult observers are shown pairs of faces that belong to the adjacent facial expressions along the continuum. They are required to compare two sequentially presented images and determine which of the first two matches a third image (Calder et al., 1996; Etcoff & Magee, 1992). Categorical perception is inferred if the point of category shift from the identification task predicts the point along the continuum of peak discrimination performance.

1.2 Categorical Perception of Emotional Facial Expressions in Children

From early in development, infants can differentiate between some facial emotional expressions. From birth, infants can discriminate static examples of happy and sad faces, happy and surprised, and sad and surprised facial emotional expressions (Field, Woodson, Greenberg & Cohen, 1982). Infants as young as a few hours old prefer to look at happy faces compared to fearful faces (Farroni, Menon, Rignato, & Johnson, 2007). Three-month-olds can differentiate between smiling and frowning faces, in both strangers and familiar caretakers (Maurer & Barrera, 1981). By 12-months, infants use the emotional expressions of others to guide their own behavior. For example, when placed on a visual cliff, infants reference their mother's facial emotional expressions before crossing the cliff. Sorce and colleagues (1985) found that if a mother's facial emotional expression was happy, but not sad or fearful, infants were more likely to cross the cliff.

There has been limited research into categorical perception of facial emotional expressions in infants and toddlers. In particular, there are questions about the developmental onset of categorical perception, and whether or not categorical perception develops concurrently for each of the basic emotional expressions. At 7 months of age, infants can categorically perceive faces along a happy to fear continuum but only when habituated to happy and not to fearful faces (Kotsoni, de Haan & Johnson, 2001; Nelson, Morse & Leavitt, 1979; Nelson & Dolgin, 1985). Researchers have also used a combination of looking-time and ERP techniques to assess infants' ability to categorically perceive facial emotional expressions, especially along the Happy-Sad continuum (Leppanen et al., 2009). In this study, researchers demonstrated that by 7-months of age, attention-sensitive ERPs over frontocentral scalp regions did not differentiate between within-category facial emotional categories, but showed clear allocation of attention when presented with faces between category boundaries. Looking-time results demonstrated that infants' differentiated facial expressions between categories, but discrimination was not tested for within category faces. Although it might appear that categorical perception along the Happy-Sad faces is present as year as 7-months, these results are only conclusive for implicit measures of behavior. Here, we investigate looking-time and pointing to evaluate when explicit behaviors support categorical perception.

A recent study used a conservative looking-time methodology to investigate categorical perception along happy-sad and happy-angry continua. Six-, 9- and 12-month-olds were tested on their ability to discriminate faces between and within both category boundaries. Results suggested that 9- and 12-month-old infants could differentiate between faces across the category boundary in the Happy-Angry continuum, but none of these age groups could do so for the Happy-Sad continuum (Lee, Cheal & Rutherford, 2015). The interpretation of findings was that infants might be capable of categorical perception only along continua of emotions that are relevant to them. As infants become mobile, threat detection mechanisms might bias infants to pay more attention to facial expressions such as angry or fear faces rather than sad faces. This might lead to an earlier development of categorical perception along continua that showed happy versus angry or fear, but not sad, faces. The categorization of happy versus sad faces might come online later in development, when sadness can inform a child's decisions about their own or others' behavior. Recent evidence suggests that categorical perception along the happy-sad continuum develops by 3.5 years of age (Cheal & Rutherford, 2011). These two studies together suggest that categorical perception along the happy-sad continuum develops between 12 months and 3.5 years of age (Cheal & Rutherford, 2011; Lee, Cheal & Rutherford, 2015). Within this age range, the question remains whether categorical perception along the happy-sad continuum might occur earlier than 3.5 years of age.

1.3 The current study

The focus of the current study was the development of categorical perception in a happy-sad continuum. The prediction that categorical perception may develop by 26-months is based on the assumption that the age of development of a specific contrast may be related to when an emotion becomes relevant to an infant's behavioral choices. By 26 months of age, young toddlers are able to generate a functional behavioral response to both happiness and sadness, and begin to demonstrate a capacity for empathic behavior (Vaish & Warneken, 2012; Dunfield & Kuhlmeier, 2013). Thus, the current study investigates whether categorical perception can be demonstrated in 26-month-old toddlers along a Happy-Sad continuum.

2. Methods

2.1 Participants

Twenty-four toddlers participated (14 boys, mean age = 26M 26D, range: 25M14D to 28M2D). Nine additional infants participated but were not included in the final analysis due to: fussiness (3), parental interference (1) or failure to complete the task (5). Participants were recruited through a developmental database. Each child received a toy and certificate for participating in the study.

2.2 Stimuli

Stimuli in this experiment consisted of images from a morphed continuum of facial emotional expressions (Figure 1). The endpoint anchors of the continuum were coloured photographs (100% Happy and 100% Sad) from the NimStim Face Stimulus Set

(Tottenham et al, 2009). A single actress from (Actress Number 1) was used to create the images.

The morphed continuum was created using Morpheus v1.85 software. This software requires the user to supply matching locations on two anchor images, then it interpolates at the desired intervals to create intermediate images. The resulting continuum consisted of 9 graduated intermediate images and the two anchor (original) photographs for a total of eleven images. Each image differed from one another in increments of 10% of the entire range. Hairline and outer facial features were removed using Adobe Photoshop 7.0 by placing the face within an oval on a black background. All faces from the continuum were presented on an LCD monitor and were 18 cm in height by 16.5 cm in width.

2.3 Procedure

Participants completed two tasks for the study, (1) a Discrimination task and (2) an Identification task. During both tasks children sat in a high chair approximately 90 cm away from a 40" LCD TV screen surrounded by black curtains. An experimenter interacted with the child throughout the experiment in order to maintain their interest and to ask the probing questions during the tasks. Parents were able to see the child's response, but the child was unable to view his or her parent's reactions. Parents were instructed not to direct their child's attention to the screen during the experiment. During the procedure, classical music was played in the background at a low volume to calm children and to minimize outside distractions. Stimuli were presented using PowerPoint Presentation software by a second experimenter who was hidden behind a curtain. The entire study was video and audio recorded via cameras located directly in front and behind the child.

2.3.1 Discrimination Task

Children saw 4 familiarization trials of the 100% happy face. Each familiarization trial was shown for 10 seconds. These four familiarization trials were followed by a visual preference test that consisted of 20 trials in which a pair of faces was shown. Each pair consisted of the 100% happy face paired with one of the nine remaining intermediate faces in the Happy-Sad continuum (e.g. a 100% happy face vs. a 60% happy face) or the 100% sad face. In between trials, children saw a cartoon that served as a centralizing fixation point. Children had to focus on this point before the next trial was played. Note that given out results (below) familiarization with the 100% sad face was not conducted because it would be redundant.

The position of the 100% happy face and the order of presentation for each pair were randomized. The 100% happy face was never on the same side on more than two consecutive trials and the same pair of faces was never presented on two consecutive trials. Looking-time to each face during each trial was coded offline by 2 blind coders via video recordings of the session. Inter-reliability between coders was above 90%. Coding for each trial began when the child looked at one of the faces, and lasted a total of 10 seconds.

2.3.2 Identification Task

Children's responses were elicited using a black cardboard sheet with a pair of happy and sad cartoon faces affixed on top (see Figure 2). The cartoon faces were 14 cm in diameter and were separated by 11 cm. The side on which each face was presented was counterbalanced across children.

Training Phase 1: During Training Phase 1, the experimenter labeled the cartoon faces as "happy" and "sad" and had the child touch each face. The child could respond by either using his or her finger or a toy wand to point to a face. The child was then asked to point or touch the faces as the experimenter labeled them the happy face and the sad face. This was repeated until the child demonstrated correct identification of each of the two faces at least threes time in a row. If the child responded incorrectly, the experimenter would correctly label the faces on the board, and training would resume.

*Training Phase 2***:** In Training Phase 2, children were shown both the 100% Happy and 100% Sad faces on a TV screen. When the 100% Happy face appeared on the screen, the experimenter labeled the face as "Happy" and pointed back and forth between the two faces saying, "Look, that's a happy face, just like this is a happy face. Touch the happy face!" The experimenter did this to create the association between the two faces. The child was encouraged to touch the matching face, and was praised after doing so to re-enforce the behavior. This procedure was repeated for the sad face. The order of presentation of the faces was counterbalanced across children. Once the child successfully matched the 100% happy face and the 100% sad face from the screen to the cartoon faces on the cardboard sheet at least 3 times each, the experimenter moved onto the next phase.

Training Phase 3: In Training Phase 3, the experimenter did not label the emotion of the face on the cardboard sheet. For example, when the 100% happy face appeared on the screen, the experimenter pointed towards it and said, "Look, it's a happy face, which one does it look like?" then pointed towards each of the cartoon faces. The child had to determine which face on the board was the same emotion as the face on the TV. The experimenter corrected any incorrect responses that the child gave, and praised them when a correct response was given. This was repeated for the 100% sad face.

Training Phase 4: In Training Phase 4, the experimenter did not label the emotion on either the screen or the cardboard sheet. Instead the experimenter said, "Look at *that* face, which one does it look like?" while pointing to both cartoon faces. In order to enter the test phase the child had to correctly label the face on the TV screen as either happy or sad three times for each emotion by touching the corresponding cartoon face. Again, children were praised for correct responses and corrected for incorrect responses. Once the child met criterion, the experimenter was signaled to move onto the Test Phase.

Test Phase: In the Test Phase**,** the procedure was similar to Training Phase 4 except that children were shown the nine remaining intermediate faces of the continuum in random order. The experimenter no longer corrected incorrect responses. Once the child provided a response, the next facial expression was presented. Responses were coded from video by two blind coders. Coders were instructed to code responses in terms of the first face each child touched on the black cardboard sheet per trial. Inter-reliability between coders was above 90%.

3. Results

3.1 Discrimination Task Results

The looking times for each face on each of the 20 trials were converted into a proportion by taking the looking time to each face (100% happy or an intermediate face) and dividing it by the total amount of time spent looking at both faces. Since the face pairs were presented twice (counterbalanced for presentation side) the proportion of looking time in the two presentations were averaged across each pair of trials that included the same stimuli.

Using the average proportion of looking time towards each face (see Figure 3) we inferred the category boundaries by determining the point at which children looked longer towards the sad faces. Since the children had been familiarized to a 100% happy face, we predicted that longer looking times toward the faces that were on the "sad" side of the category boundary. If children spent a significantly longer proportion of time looking at faces in the sad category, this is evidence that they could discriminate the sad from the happy faces.

A repeated-measure ANOVA using face (intermediate faces) as the within subject variable, revealed a significant effect of Face ($F(8)=4.995$, $p<0.001$). Further analysis revealed that children did not look longer at the 90% to 60% happy faces (happy category faces) when they were paired with the 100% happy face on those trials ($t(23)=1.11$, $p = 0.913$, two-tailed). But children did look significantly longer at the 40% to 10% happy faces (sad category faces) when compared with the 100% happy face on those trails ($t(23)= 3.75$, $p = 0.001$, two-tailed). A one-sample *t*-test between the proportion of looking time to the *between* category faces, 60% happy face and 40% Happy face, revealed that infants looked significantly longer towards the 40% happy face (which fell in the "sad" category) than at the 60% happy face (which fell in the "happy" category) ($t(23)=1.83$, $p = .03$, two-tailed, $d=.44$). This pattern was not evident for faces *within* categories with the same interval physical change, as there was no significant difference in looking time between the 60% to 80% happy face ($t(23)=1.78$, $p = 0.09$, two-tailed) and the 40% to 20% happy face ($t(23)= 1.94$, $p=0.07$, two-tailed). This demonstrates an increase in toddler's discrimination accuracy occurring between the 60% Happy face and the 40% Happy face, which is where we would predict the category boundary to be located based on results from the Identification task in adults.

3.2 Identification Task Results

Children's identification responses are reported in terms of the percent of children who pointed to each image happy or sad (see Figure 4). For the 100%–60% happy faces (happy category faces), a significant percentage of the children identified these faces as "happy" (mean= 79.2%, binomial test, $p < 0.001$) and 20.8% identified them as "sad" (binomial test, p = n.s.). For the 40% happy faces (sad category faces), a significant percentage of children identified these faces as "sad" (mean = 77.6%, binomial test, $p < 0.001$) and 22.4% identified them as "happy" (binomial test, p = n.s.).

Children's percentage of responses changed across the predicted boundary between the 60% Happy and 40% Happy face. A difference of proportions test (Blalock, 1972) revealed that the percentage of responses changed significantly decreased across the 60% happy to 40% happy face ($z= 2.93$, $p= 0.002$, $\Phi = .42$, two-tailed), and their response for sad faces significantly increased across the 60% Happy to 40% Happy face ($z= 2.98$, $p= 0.001$, $\Phi = 0.43$, two-tailed). This shift in identification of the faces is where the predicted category boundary on the Happy-Sad continuum would be located.

3.3 Correlational Analysis

A correlational analysis was performed to determine whether there was a relationship between performance on the discrimination and identification tasks. The number of trials on which each child looked longer at the novel (60%-100% sad) face versus the old (100% happy) face were summed and became their overall score for the discrimination task. In the identification task, the number of test trials each child correctly identified the facial emotion of the intermediate face were summed and became their overall score for the identification task. Performance on the discrimination task was positively correlated with performance on the identification task: $r(22)= 0.347$, $p=0.04$.

4. Discussion

The results of the current study provide empirical evidence of categorical perception for emotional facial expressions along the happy-sad continuum in 26 month old toddlers. The present study builds on previous research (Kotsoni, de Haan, & Johnson, 2001; Cheal & Rutherford, 2011; Lee, Cheal, & Rutherford, 2015) examining the developmental trajectory of categorical perception of facial emotional expressions. Here, we introduce a novel paradigm that relies on the logic that underpins adult research into categorical perception, but is adapted for use with 26-months of age toddlers.

In the discrimination task, toddlers looked longer towards a face within the sad category than toward the 100% happy face, suggesting discrimination of faces across the category boundaries. In contrast, there were no significant differences in the proportion of looking time between faces within the happy category and the 100% happy face. Critically, the increase in the proportion of looking time towards the test face occurred between the 60% happy face (which was still in the happy category) and 40% happy face (which was across the boundary in the sad category). These two faces span the boundary between the happy and sad categories along the continuum. This looking time difference provides evidence that toddlers find it easiest to discriminate images between categories at the 40% and 60% faces, rather than within a category, just like adults and older toddlers tested on the same continuum (Cheal and Rutherford, 2011).

In the identification task, children predominately labeled faces within the happy category as "happy" faces and faces within the sad category as "sad". Importantly, responses to faces identification changed across the 40%-60% face boundary, such that there was a "switch" in pointing behavior at the predicted category boundary for the happy-sad continuum. Together with the discrimination task, these results demonstrate strong evidence for categorical perception, as measured using looking-time and pointing behavior, of the happy-sad continuum in 26-month-old children. These results demonstrate that categorical perception along this continuum occurs at least 16 months earlier than previous findings (Cheal & Rutherford, 2011). It might be possible that categorical perception along this continuum occurs even earlier in development (~ 18-months), and it would be important to investigate this further.

A correlational analysis indicates that toddlers' performances on the discrimination task were related to performance on the identification task. Toddlers who looked longer at the sad face during the discrimination task, also correctly pointed to more faces during the identification task. These findings seem to suggest that the mechanisms that underlie perceptual abilities in processing facial emotional information may develop in tandem with social cognitive abilities in a different modality (in our study, active pointing). This finding is novel, as previous research had not tested a relationship between individual performances on the two tasks. Furthermore, this finding could have interesting implications on the relationship between performance on looking-time tasks and active pointing tasks, in regards to emotional development and understanding.

The development of empathy and empathetic behaviors (comforting, sharing, emotional contingency) are thought to develop between the ages of 18-months to 24-months (Vaish & Warneken, 2012; Dunfield & Kuhlmeier, 2013). Therefore, it is not surprising that we find evidence for categorical perception at 26-months, but not at 12-months of age. During this time, children are increasing encouraged to attend to, participate, and engage in empathic social interactions with others within their environment. One could speculate that sensitivity to or an increased attention to sad faces during this time influences the development of categorical perception along this continuum. Alternatively, this mechanism might come online to accommodate interpretation of facial expressions (sadness in this case) as these social interactions become important and relevant to the child. It is entirely possible that if the paradigm were modified even more to better suit testing of 18-month-old infants, we could find this ability comes online much earlier.

Overall, the results of the current study provide empirical evidence of categorical perception for emotional facial expressions along the happy-sad continuum in young toddlers. This mechanism may develop earlier than previously thought (Cheal & Rutherford, 2011). It is possible that categorical perception along this continuum may develop earlier than 26-months, but this would require further investigation. Future work could include further investigation into the relationship between categorical perception along the happy-sad continuum and the emergence of overt empathic behaviors and other social cognitive skills.

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References

Calder, A. J., Young, A. W., Perrett, D. I., Etcoff, N. L., & Rowland, D. (1996). Categorical perception of morphed facial expressions. *Visual Cognition*, *3*, 81–117.

Cheal, J. L., & Rutherford, M. D. (2010). Mapping emotion category boundaries using a visual expectation paradigm. *Perception, 39,* 1514–1525.

Cheal, J. L., & Rutherford, M. D. (2011). Categorical perception of emotional facial expressions in preschoolers. *Journal of Experimental Child Psychology, 110*, 434–443.

Bornstein, M.H., Kessen, W., Weiskopf, S. (1976). Colour vision and hue categorization in young human infants. *Journal of Experimental Psychology, Human Perception, and Performance, 2(1),* 115-129.

Darwin, C.R. (1872). The expression of the emotions in man and animals. D. Appleton and Company: New York.

Dunfield, K.A. & Kuhlmeier, V.A. (2013). Classifying prosocial behavior: Children's responses to instrumental need, emotional distress, and material desire. *Child Development, 84(5)*, 1766-1776.

de Gelder, B., Teunisse, J. P., & Benson, P. J. (1997). Categorical perception of facial expressions: Categories and their internal structure. *Cognition & Emotion*, *11*(1), 1-23.

Etcoff, N. L., & Magee, J. J. (1992). Categorical perception of facial expressions. *Cognition, 44*, 227–240.

Farroni, T., Menon, E., Rigato, S., & Johnson, M.H. (2007). The perception of facial expressions in newborns. *European Journal of Developmental Psychology, 4*(1), 2-13.

Field, T.M., Woodson, R.W., Greenberg, R., and Cohen, D. (1982). Discrimination and imitation of facial expressions by neonates. *Science, 218,* 179-181.

Harnad, S. (1987). Psychphysical and cognitive aspects of categorical perception : critical overview. In S. Harnad (Ed.), *Categorical perception : The groundwork of cogntiion, (pp.1-25)*. New York : Cambridge University Press.

Kotsoni, E., de Haan, M., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception, 30(9),* 1115–1126.

Lee, V., Cheal, J. L., & Rutherford, M. D. (2015). The development of categorical perception of facial emotions. *Journal of Infant Behavior and Development,* 40, 95-102

Lee, V. & Kuhlmieier, V.A. (2013). Young children show a dissociation in looking and pointing behavior in falling events. *Cognitive Development, 28,* 21-30.

Maurer, D. & Barrera, M.E. (1981). The perception of facial expressions by three-month-olds. *Child Development, 52(1),* 203-206.

Nelson, C.A. and Dolgin, K.G. (1985). The Generalized Discrimination of Facial Expressions by Seven-Month-Olds Infants. *Child Development, 56*(1), 58-61.

Nelson, C.A., Morse, P.A., & Leavitt, L.A. (1979). Recognition of facial expressions by seven-month-old infants. *Child Development, 50,* 1239-1242.

Siegel, J. & Siegel, W. (1977). Categorical Perception of Tonal Intervais: Musicians can't tell sharp from flat. *Perception and Psychophysics, 21(5),* 399-407

Sorce, J. F., Emde, R. N., Campos, J., & Klinnert, M. D. (1985). Maternal emotional signaling: Its effect on the visual cliff behaviour of 1-year-olds. *Developmental Psychology, 21*, 195–200.

Tottenham, N., Tanaka, J.W, Leon A.C., McCarry, T., Nurse, M., Hare, T.A., Marcus, D.J., Westerlund, A., Casey, B.J., and Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Research, 168(3),* 242-249.

Vaish, A., & Warneken, F. (2012). Social-cognitive contributors to young children's empathic and prosocial behavior. In J. Decety (Ed.), *Empathy: From Bench to Bedside* (pp. 131-146). Cambridge: MIT Press.

Zahn-Waxler, C., Radke-Yarrow, M., Wagner, E., & Chapman, M. (1992). Development of concern for others. *Developmental Psychology, 28*, 126–136.

Figure 1. Stimuli of facial emotional expressions used in both the Identification and Discrimination Tasks. The continuum end points represent the 100% Sad (Left) and 100% Happy (Right) faces. Each intermediate face differs from one another in increments of 10% of the entire range of faces.

Figure 2. Cardboard response sheet used to elicit verbal and pointing responses from children during the Identification Task. The position of the happy and sad faces were counterbalanced per participant.

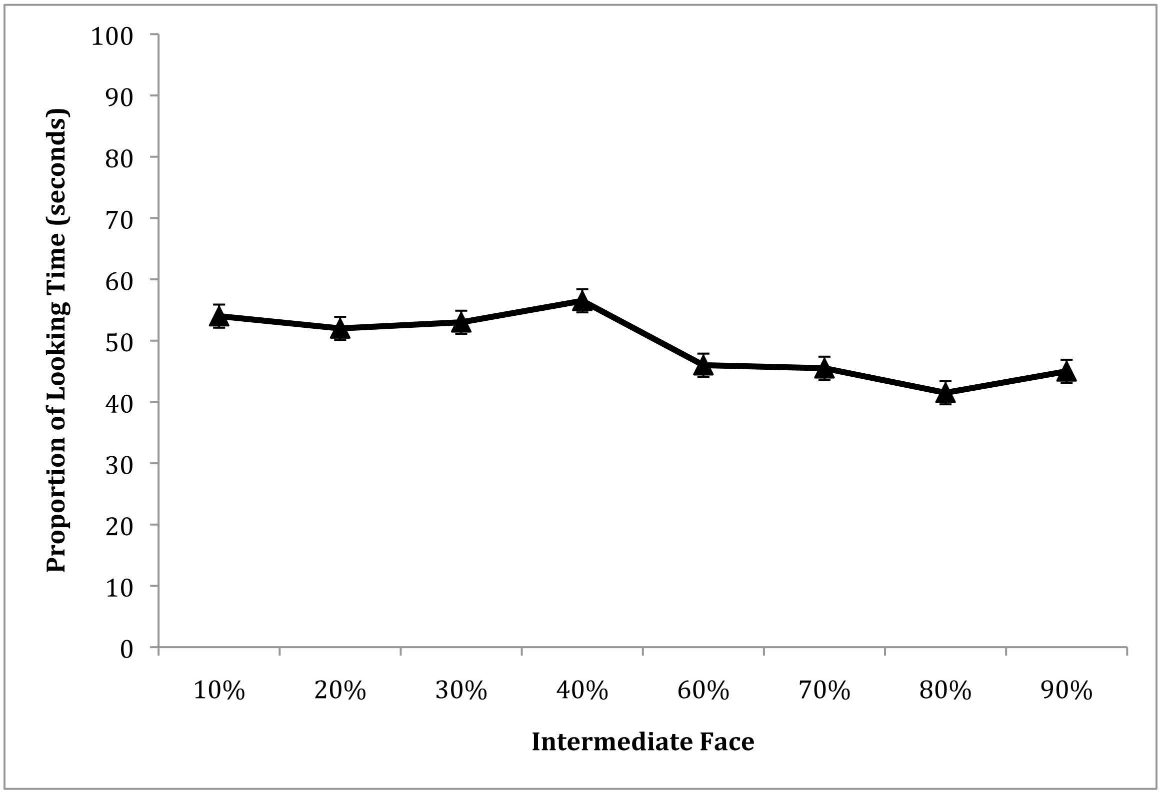


Figure 3. The mean proportion of looking time towards the 9 intermediate faces of the Happy-Sad continuum when paired with the 100% happy face. Error bars depict standard error and asterisks denote statistical significance at p <.05

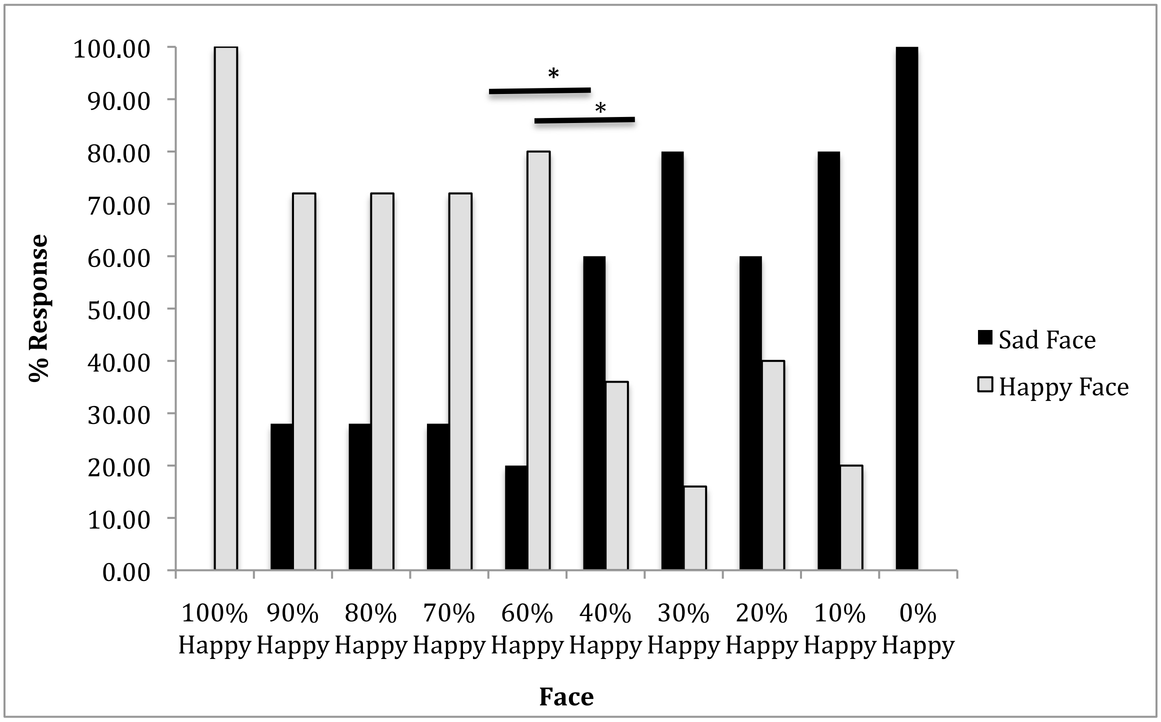


Figure 4. The mean percentage of children's' responses per face. Asterisks denote statistical significance at p <.05.

CHAPTER 4

EMOTION EXPRESSION DISCRIMINATION PREDICTS EMOTION LABEL PRODUCTION IN TODDLERS

This chapter has been submitted to the *European Journal of Child Development* for publication. At of the submission of this thesis, this chapter was invited for resubmission with revisions. Copyrights agreements will be obtained from the publisher and transferred to McMaster University, and the Library Archives Canada once the article has been accepted for publication by the journal.

Preamble

The acquisition of emotion information is an important aspect of social development. An understanding of emotion cues can aid in the prediction of others' thoughts, desires, and feelings across a variety of contexts. In turn, this understanding allows the observer to make inferences about the behaviour of others' and it also helps to modulate their own responses. Given the importance of emotion understanding in successful social interactions, it would be not surprising that attention to and the processing of emotional cues develop early in childhood.

An understanding of emotion cues may start with the perception of facial expressions as these signals are easily recognized (Darwin, 1965; Izard, 1994). Some researchers suggest that an early understanding of emotions via facial expressions is the foundation of all later emotion understanding (Harris, 1989). Indeed, infants from birth attend preferentially to faces (Farroni, Menon, Rigato, & Johnson, 2007) or objects that resemble faces (top-heavy, high contrast figures- Johnson, Dziurawiec, Ellis, Morton, 1991). Although it is difficult to assess how infants interpret the emotional information from faces, they are at the very least capable of distinguishing between the physical features of facial emotional expressions and responding appropriately to them (Caron, Caron, & MacLean, 1988; Barrera & Maurer, 1981; Walker-Andrews & Lennon, 1991).

Later in development, preschoolers start using labels (i.e. language) to identify basic emotions including happiness, sadness, anger, and fear (Denham & Couchoud, 1990). Research suggests that after 3-years of age language becomes the more dominant mode of describing, categorizing, and identifying emotional information from social others (Russell, 1990, Russell & Widen, 2002). In emotion labeling studies, researchers argue that an individual's emotional understanding relies on the formation of an association between emotion labels (learned from caregivers and social others) and behavioural outcomes of those emotions. Further, parents often capitalize on preschoolers' attention to emotion information by labeling emotions and talking about their consequences (Lagattuta & Wellman, 2002).

It seems unlikely that these two modes used in learning (observations of facial expressions and emotion labeling) about emotions develop in isolation of each other. It would be reasonable to assume that the discrimination of facial emotional expressions and emotion labeling develop together within an emotion-specific process. Further, there may exist a bi-directional relationship between the development of the two modes of learning, such that the ability to perceptually discriminate between facial expressions may be associated with a larger emotion vocabulary or visa versa.

Evidence in support of this hypothesis comes from adult literature in categorical perception of unfamiliar objects (Newell & Bulthoff, 2002) and unfamiliar faces (Kikutani, Robertson, & Hanley, 2008). When adults are asked to make categorical discrimination between unfamiliar faces without prior experience or labels associated with each face, categorical perception does not occur (Kiktutani, Robertson, & Hanley, 2008). But, in conditions where adults are given labels for the faces that make up the ends of a continuum (making them "familiar"), categorical perception occurs. Notably, discrimination between category faces improved with the use of labels for the unfamiliar faces. It is difficult to speculate on why labels increase the ability to discriminate between unfamiliar faces, but it could be because participants may pay more attention to labeled faces. Similarly, toddlers who use more emotion labels may pay more attention to subtle changes in facial emotional expressions because they attend more to facial emotional expressions in general, or visa versa.

In this exploratory study, I investigated the relationship between perceptual discrimination of facial expressions (via looking-time) and emotion vocabulary size (i.e. emotion labels). The study utilized a familiarization-based paradigm to measure 26-month-olds ability to perceptually differentiate a 100% happy face with sad face intermediates. Second, the size of a child's general vocabulary and their emotion vocabulary (i.e. emotion labels) were collected using parent reports. Parents were given a standardized vocabulary questionnaire and list of predetermined basic emotion words (i.e. happy, sad, angry, etc.). The results suggest that a positive correlation exists between a greater perceptual sensitivity to physical differences between two facial emotional expressions (i.e. happy and sad) and a larger emotion vocabulary (as reported by parents).

This is the first study to demonstrate a potential relationship across the two different modes used in learning about emotions. Importantly, it suggests that an emotion-specific process that facilitates learning about emotion information across different modes. I suggest that further investigation is warranted into the nature of this relationship so that we can gain a better understanding of how emotion knowledge develops.

Abstract

It is possible that the visual discrimination of emotion categories and emotion word vocabulary both develop with the development of common emotion-specific processes. In contrast, it is possible that both develop with general intelligence. The current study contrasts these two possibilities. Twenty-three 26-month-olds participated in a habituation-based visual perceptual discrimination task involving emotional facial expressions. After familiarization to 100% happy face, toddlers were tested for their visual preference for a sad face given a side-by-side presentation. Parental report was used to quantify production of emotion words and language generally. Visual preference for the novel emotion (sad) in the discrimination task correlated with emotion word vocabulary size: $r(23)=0.37$, $p = 0.009$, but not with overall vocabulary size.

Keywords: Emotion Development, Emotion, Facial Emotional Expressions, and Emotion Labels

1. Introduction

Adults are experts in decoding emotional information using multiple cues including: body language (Van dan Stock, Righard, & de Gelder, 2007), voice pitch and tone (Gobl & Chasaide, 2003), and language (Feldman-Barrett & Lindquist, 2007). These cues are integrated, enabling people to interpret and predict the behaviour of others, as well as modulate their own response. Yet, little is known about the developmental trajectory of processes associated with the integration of emotional information. It is unclear whether associations develop between cues within an emotion-specific process or whether the process develops overtime with general intelligence. This study is designed to explore the association between two developing skills: discrimination of facial emotional expressions and emotion label production.

Both perception and interpretation of emotions develops in infancy. From birth, infants orient towards, attend to, perceive, and categorize emotional facial expressions. For example, neonates are able to discriminate and imitate smiles, pouts, and gasps (Field, Woodson, Greenberg, & Cohen, 1982). Newborns can differentiate between and show a visual preference for happy faces over sad faces (Farroni, Meenon, Rigato, & Johnson, 2007). Between 3-5 months, infants can discriminate between expressions including fear, anger, sadness, joy, and surprise (Schwartz, Izard, & Ansul, 1985; Younge-Browne, Rosenfeld, & Horowitz, 1977). By 3.5 months, infants can match vocal tones to facial expressions (Walker-Andrews & Lennon, 1991). Emotion expressions are perceived categorically within the first year of life (6-, 9- and 12-months; Lee, Cheal, Rutherford, 2015, Kotsoni, de Haan, & Johnson, 2001).

Observation of facial emotional expressions and reactions from caregivers help modulate infants' own behaviour across different contexts. Infants and children use caregiver's facial emotional expressions to guide behavior (social referencing) in both familiar and ambiguous situations. In turn, for example, infants use a caregiver's expression to judge whether to accept the overtures of a stranger (Feinman & Lewis, 1983), to approach an ambiguous toy (Gunnar & Stone, 1964), or to cross a visual cliff (Sorce, Emede, Campos, Klinnert, 1985). Further, by the age of 14-months, infants will use facial emotional expressions to predict others' goal-directed behavior (Phillips, Wellman, Spelke, 2002).

Parents capitalize on children's tendencies to seek emotional information by talking about the outcomes and consequences of emotions. The ability to label and discuss experiences with emotions is a central component of emotional competence according to Saarni (1999). Parent-child conversations, particularly about the causes of negative emotions, enable children to think causally about feelings (Lagattuta & Wellman, 2002). Talking about emotions helps young children understand, represent, and response to others' emotions appropriately. As children enter the preschool years, labeling and contextual information about emotions become important aspects of identifying emotions (Russell, 1990, Russell & Widen, 2002).

Both emotion expressions and emotion labels facilitate identification of expressions and support the ability to match emotional labels with a given context. It would not be surprising to find evidence of bi-directional influences during development across 1) the ability to perceive and discriminate facial emotional expressions and 2) labeling of emotions. Evidence from the adult literature on labeling and face perception suggests that a link is possible (Kiktutani, Robertson, & Hanley, 2008). Participants in this study were tested on their ability to categorically perceive along a continuum created using two previously unfamiliar faces. Results suggest that categorization did not occur when participants had no previous labels or exposure to the end-points of the continuum. However, when participants were given labels (i.e. names) for each of the end point faces, categorization occurred. Additionally, labels enhanced the ability to discriminate faces across the category boundary. Although this example was specific to unfamiliar faces, it seems likely that labeling stimuli plays an important role in categorical perception. This brings into question whether labeling of emotions may also influence the perception of facial expressions in infants and toddlers, as they begin to use emotion labels.

The purpose of the current study was to investigate the relationships between these two developing skills. We predicted a correlation between the two, but no relationship between expression perception and language production generally. In order to test this prediction, we measured 26-month olds' visual preference (using looking-time) for a novel emotion expression (sad faces) after being habituated to happy faces, similar to the method Peltola, Forssman, Puura, van Ijzendoorm, and Lepanen (2015) used. We used parental report questionnaires to measure production of emotion labels and overall language production.

2. Methods

2.1 Participants

Twenty-three toddlers participated in the study (13 boys, mean age = 26M 26D, range: 25M 14D to 28M 2D). Ten additional infants participated but were not included in the analysis due to: fussiness (4) or failure to complete the task (6). Participants were primarily from a midsize city and were recruited through a developmental psychology recruitment database. Parents were approached in the maternity ward of the local hospital and those who were interested in participating in developmental research had their names entered into the database. Each child received a toy and certificate for participating in the study.

2.2 Stimuli

Stimuli in this experiment consisted of images from a continuum of facial emotional expressions created using morphing software (Figure 1). The endpoints of the continuum were coloured photographs (100% Happy and 100% Sad) from the NimStim Face Stimulus Set (Tottenham et al, 2009). Images of single actress (Actress Number 1) were used to create the continuum.

The continuum was created using Morpheus v1.85 software. This software requires the user to supply matching locations on two anchor images (e.g. the tip of the nose, or the left corner of the mouth). It then interpolates between each pair of points at the desired intervals to create intermediate images. The resulting continuum consisted of 9 graduated novel images plus the two original photographs for a total of eleven images. Adjacent images are equally physically different from one another, and each image differed from each immediate neighbor by an increment of 10% of the entire physical change. Hairline and outer facial features were removed using Adobe Photoshop 7.0 by placing the face within an oval on a black background. Faces from the continuum were presented on an LCD monitor and were rendered as 18 cm in height by 16.5 cm in width.

2.3 Procedure

Children sat in a high chair approximately 90 cm away from a 40" LCD TV screen surrounded by black curtains. Parents sat quietly behind the child in the corner of the room, therefore they were able to see the child's response, but the child was unable to view his or her parent's reactions. Parents were instructed not to interact or direct their child's attention to the screen during the experiment. During the procedure, classical music was played in the background at a low volume to minimize outside distractions. Stimuli were presented using PowerPoint Presentation software by a second experimenter who was hidden behind a curtain. The entire study was video recorded via two cameras, one located directly in front of and one behind the child.

2.4 Discrimination Task

Children saw 4 familiarization trials using the 100% happy face. In each familiarization trial, the image was shown for 10 seconds. During the test trials, children saw 18 trials in which a pair of faces was shown. Each pair consisted of the 100% happy face paired with one of the nine remaining intermediate faces in the Happy-Sad continuum (e.g.. a 100% happy face vs. a 60% happy face). In between trials, children saw a cartoon that served as a centralizing fixation point. Children had to focus on this point before the next trial was played.[3]

[3] It should be noted that children in this study were concurrently participating in a study looking at facial emotional processing along the Happy-Sad continuum. The discrimination task was one of two perceptual tasks children completed during their visit. Only looking-time results from the discrimination task were used to correlate with emotional language abilities.

The left or right position of the 100% happy face was counterbalanced between trials. The 100% happy face was never on the same side on more than two consecutive trials and the same pair of faces was never presented on two consecutive trials. Looking-time to each face during each trial was coded offline by 2 blind coders via video recordings of the session. Inter-reliability between coders was above 90% (Cohen's kappa = 0.93). Coding for each trial began when the child looked at one of the faces and lasted a total of 10 seconds.

2.5 Emotion Words Questionnaire

This questionnaire was created for the purposes of this study. The 9 emotion-related words included: happy, smile, frown, sad, mad, afraid, angry, scared, and love. Parents were instructed to report all words on the list that their child used expressively to label emotions. Parents completed the questionnaire during the testing session.

2.6 MacArthur-Bates Communicative Development Inventory: Words and Sentences

The MacArthur-Bates Communicative Development Inventory: Words and Sentences (MDCI: Words and Sentences; Fenson et al., 2007) is used to assess the expressive vocabulary and grammatical knowledge of children between the ages of 16 and 30 months. This parent-report instrument has generally been shown to provide valid assessments of young children's language development. The questionnaire consists of two sections: a vocabulary checklist and a section that measures morphology and syntax. Parents in the current study were instructed to fill out the vocabulary checklist only. The vocabulary checklist of a 680-words was organized into 22 semantic categories. Eleven of the categories contain only nouns. The other categories contain sounds that young children often use to label objects or animals, games and routines, verbs, adjectives, and closed class words. Parents completed the questionnaire during the testing session.

2.7 Measures for correlational analyses

To measure children's looking time preference between the 100% Happy face and the Sad faces (Images 5-9) during the discrimination task two preferential scores were calculated. As the 100% Happy face was used in the familiarization trials, the sad faces were regarded as the preferred (novel) face. Thus, looking time preferences were calculated as looks towards the sad faces. The "Simple Preference Score" used the difference between the average looking time to the overall preferred face (i.e. Sad faces) and the non-preferred faces (i.e. 100% Happy). Additionally, we included an "Alternative Preference score" as used in Yamaguchi, Kuhlmeier, Wynn, vanMarle, 2009, which is the proportion of time spent looking at the overall preferred face across all test trials: the looking time to sad faces divided by the sum of the looking time to the happy and sad faces. The two test preference scores are highly correlated: $r(23) = 0.93$.

2.8 Emotion Labels Questionnaire and the MCDI

Scores for the total number of expressive emotion words and total vocabulary were cumulative scores reported by the parents on the Emotion Words Questionnaire (total of 9 words) and the MCDI (total of 680 words).

3. Results

Children looked an average of 19.7 seconds (SE = 1.7, Range = 5.4 to 36.4 seconds) to the sad faces and 16.4 seconds (SE = 1.2, Range = 5.0 to 27.20 seconds) to the 100% happy face, when the two faces were presented together. Children's looking-time towards the sad faces were significantly longer than towards the 100% happy face, $t(23)= 3.75$, $p = 0.01$.

3.1 Word Performance

On average, parents reported that children expressively used 4.8 words on the Emotion Words Questionnaire. Parents reported that on average children spoke 345 words from the MCDI.

3.2 Correlation analyses

For this group of children, the looking time preference in the discrimination task correlated with performance on the Emotion Word Questionnaire: $r(23)=0.37$, $p = 0.009$ for the Simple Preference Score and $r(23)= 0.28$, $p = 0.03$ for the Alternative Preference Score (Figure 2). Specifically, a stronger preference for the sad face, measured as a looking time difference, during the discrimination task correlated with the use of more emotional words. In contrast, this relationship was not found in the performance in the MDCI: $r(23)= 0.21$, $p = 0.08$ Simple Preference Score and $r(23)= 0.17$, $p = 0.12$ Alternative Preference Score (Figure 3). Performance on a social perceptual task correlated significantly with the expressive use of emotional words but not overall size of vocabulary.

4. Discussion

These results suggest that a better-developed ability to discriminate between happy and sad faces (as measured by looking time towards a novel stimuli) is predicted by the number of emotion labels used expressively as reported by parents of 26-month-old toddlers. Children who looked longer at the novel faces during test trials used more emotion labels in their vocabulary. Importantly, this relationship was seen for overall vocabulary. The ability to discriminate subtle changes in facial emotional expressions is related to the use of more emotion labels.

This pattern of results supports the hypothesis that a single underlying psychological process may underlie the development of emotion expression perception and emotion word acquisition. It is not consistent with the hypothesis that they are independent. More generally, this study suggests a specific link between early perceptual ability and later social cognitive skills.

Previous studies have looked at the relationship between looking-time to facial emotional expressions and other social features of emotions. For example, an infants' reaction to a caregivers lack of facial emotional response to their behaviour is predictive of later attachment style (Braungart-Rieker, Zentall, Likenbrock, Ekas, Oshio, & Planalp (2014). Attention to fearful faces at 7-months of age is predictive of infant-mother attachment style at 14-months Peltola, Forssman, Puura, van Ijzendoorm and Leppanen (2015).

Identifying the mechanisms that mediates this relationship is beyond the scope of this paper. However, we speculate on a number of possibilities. First, children who naturally attend to faces (particularly emotion expressions) may more quickly develop their ability to discriminate facial emotions. In turn, this may increase sensitivity to emotion information in general, which would include use of emotion labels. Second, children who naturally attend more to emotion labels could have driven this effect. Perhaps having the label for a particular emotion increases attention to the faces paired with that particular label, and thus, increases perceptual expertise. However, we think this later explanation might be unlikely since research suggests that use of facial information tends dominate emotion information gathering (during infancy) while later starting in the preschool years, emotion labels become more important identifiers (Widen & Russell, 2004). Therefore, it seems likely that children first pay more attention to faces and use faces to acquire rudimentary emotional information. Then, through increasing expertise, emotion understanding is co-opted by language development via labeling and conversations about emotions.

Parents likely play an important role in the relationship between the ability to discriminate facial emotional expressions and the acquisition of emotion labels. Previous research demonstrated that children between 2 to 5 years of age quickly develop sophisticated skills for talking, reasoning about, and explaining emotional experiences. During these years, emotional vocabulary expands (Ridgeway & Kuezaj, 1985), explanations about causes and consequences of emotions (Bretherton & Beeghly, 1982), and talk about people's internal states (Dunn & Brown, 1993) increases. It is likely that around this time, parent-child discussion about emotions also increases. During these discussions, it is possible that parents are also drawing children's attention to facial expressions associated to those emotions, including demonstrating the facial expression and pointing out facial expressions of individuals that symbolize a certain emotion. This increase in attention to facial emotional expressions paired with verbal information about the emotion (including labels) could have resulted in the correlated demonstrated in the current study. Further studies should investigate the influence parental conversations about emotions on this relationship. All speculations and the directionality of these mechanisms certainly warrant further empirical investigation.

It should be noted that one underlying explanation that is not supported by these data was that discriminatory ability for facial emotional expressions was not correlated to a larger overall vocabulary. This would have been predicted if general intelligence were the driving force behind increased perceptual sensitivity to faces. Instead, our findings suggest that the relationship between individual differences in discriminatory ability and production of emotional labels are specific to the emotion domain. Additionally, this also means that better performance on our tasks and the number of emotion labels produced was not simply a reflection of general intelligence.

In conclusion, the current study finds a correlation between early emotion perception ability and later social cognitive skills. This association may be a result of an underlying social competence that supports both of these skills, it may be a result from differences across parents in the support of emotion development, or it could have another source. Our data suggest that the association is not due to differences in general intelligence, which would predict an association between emotion discrimination and overall productive vocabulary.

References

Braungart-Rieker, J.M., Zentall, S., Likenbrock, D.M., Ekas, N.V., Oshio, T., & Planalp, E. (2014). Attachment in the making: Mother and father sensitity and infants' responses during the still-face paradigm. *Journal of Experimental Child Psychology, 125,* 63-84

Bretherton, L. & Beeghly, M. (1982). Talking about internal states. The acquisition of an explicit theory of mind. *Developmental Psychology, 18,* 906-921

Bullock, M. & Russell, J.A. (1986). Concepts of emotion in developmental psychology. In C.E. Izard & P. B. Read (Eds.). *Measuring emotions in infants and children* (vol. II. 203-237). Cambridge: Cambridge University Press.

Darwin, C. (1872). The Expressions of the Emotions in Man and Animals. *London:* John Murray

Denham, S.A. (1998). Emotional development in young children. *New York:* Guildford Press.

Dunn, J. & Brown, J.R. (1993). Early conversations about causality: Content, pragmatics, and developmental change. *British Journal of Developmental Psychology, 11,* 107-123

Dunn, J. & Brown, J.R. (1994). Affect expression in the family: Children's understanding of emotions and their interactions with others. *Merrill-Palmer Quarterly, 40,* 120-137

Etcoff , N.L. & McGee, J.J (1992). Categorical perception of facial expressions. *Cognition, Sept 44(3)*, 277-240

Ekman, P., Friesen, W.V., O'Sullivan, M., Chan, A, Diacoyanni-Tarlatzis, I, Heider, K., Krause, R., LeCompte, W.A., Pitcairn, T., Ricci-Bitti, P.E., Scherer, K., Tomita, M., Tzavaras, A. (1987). Universals and cultural differences in the judgments of facial expressions of emotion. *Journal of Personality and Social Psychology*, *Vol 53(4),* 712-717.

Farroni, T., Menon, E., Rigato, S. & Johnson, M.H. (2007). The perception of facial expression in newborns. *European Journal of Developmental Psychology, 4(1),* 2-13

Fehr, B. & Russell, J.A. (1984). Concept of emotion viewed from a prototype perspective. *Journal of Experimental Psychology: General, 113,* 464-486

Feldman Barrett, L. Lindquist, K.A., & Gendron, M. (2007). Language as context for the perception of emotion. *Trends in Cognitive Sciences, Volume 11, Issue 8*, Pages 327–332

Feinman, S. & Lewis, M. (1983). Social Referencing at Tem Months: A Second-Order Effect on Infants' Reponses to Strangers. *Child Development, 54(4)*, 878-887

Fenson, L., Dale, P, Reznick, J., Thal, D., Bates, E. Hartung, J., Pethick, S. & Reilly, J (2003). MacArthur communicative development inventories: User's guide and technical manual. Baltimore, M.D.: Paul H. Brookes.

Field. T.M., Woodson. R., Greenberg. R. & Cohen. D. (1982). Discrimination and imitation of facial expressions by neonates. *Science, 218*, 179-151.

Gohl, C. & Chasaide, A.N. (2003). The role of voice quality in communicating emotion, mood and attitude. *Speech Communication*, *Volume 40, Issues 1–2*, Pages 189–212

Gunnar, M.R. & Stone, C. (1964). The Effects of Positive Maternal Affect on Infant Responses to Pleasant, Ambiguous, and Fear-Provoking Toys. *Child Development, 55(4),* 1231-1236

Kotsoni, E., de Haan, M., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception, 30,* 1115-1125.

Lagattuta, K.H. & Wellman, H.M. (2002). Differences in early parent-child conversation about negative vs. position emotions: Implications for the development of psychological understanding. *Developmental Psychology, 38(4),* 564-580

Lee, V., Cheal, J. L., & Rutherford, M. D. (2015). The development of categorical perception of facial emotions. *Journal of Infant Behavior and Development,* 40, 95-102

Nelson, C. A. (1987). The recognition of facial expressions in the first 2 years of life, Mechanisms of development. *Child Development*, 58, 889-909.

Nelson, C. A., Morse, P. A., Leavitt, L. A. (1979). Recognition of facial expressions by seven-month-old infants. *Child Development*, 50, 1239-1242.

Nelson, C.A. and Dolgin, K.G. (1985). The Generalized Discrimination of Facial Expressions by Seven-Month-Olds Infants. *Child Development, 56*(1), 58-61.

Peltola, M.J., Forssman, L., Puura, K., van IJzendoorm, M.H. & Leppänen, J.M. (2015). Attention to Faces Expressing Negative Emotion at 7 months predicts attachment security at 14 months. *Child Development, 86(5),* 1321-1332

Phillips, A.T., Wellman, H.M., Spelke, E.S. (2002). Infants' ability to connect gaze and emotional expression to intentional action. *Cogntion, 85(1),* 53-78

Ridgeway, D. & Kuczaj, S. (1985). Acquisition of emotion-descriptive language: Receptive and productive vocabulary norms for ages 18 months to 6 years. *Developmental Psychology, 21,* 901-908

Russell, J.A. (1990) The preschooler's understanding of the causes and consequences of emotion. *Child Development, 61,* 1872-1881

Russell, J.A. & Widen, S.C. (2002). A Label Superiority Effect in children's categorization of facial expressions. *Social Development, 11,* 30-52

Saarni, C.A. & Harris, P. (1989). Children's understanding of emotion. Cambridge, England. Cambridge University Press.

Schultz, Izard, & Ackerman, 2001

Schwartz, G. M., Izard, C. E., & Ansul, S. E. (1985). The 5-month-old's ability to discriminate facial expression of emotions. *Infant Behavior and Development*, 8, 65-77.

Serrano, J. M., Iglesias, J., & Loeches, A. (1992). Visual discrimination and recognition of facial expressions of anger, fear, and surprise in 4- to 6-month-old infants. *Developmental Psychobiology*, *25*, 411-425.

Tottenham, N., Tanaka, J.W, Leon A.C., McCarry, T., Nurse, M., Hare, T.A., Marcus, D.J., Westerlund, A., Casey, B.J., and Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Research, 168(3),* 242-249.

Van den Stock, J., Righart, R., & de Gelder, B. (2007). Body expressions influence recognition of emotions in the face and voice. *Emotion, Vol 7(3),* 487-494

Walker-Andrews, A.S. & Lennon, E. (1991). Infants' discrimination of vocal expressions: Contributions of auditory and visual information. *Infant Behavior and Development, 14,* 131-142

Widen, S.C. & Russell, J.A. (2004). The relative power of an emotion's facial expression, label, and behavioural consequence to evoke preschooler's knowledge of its cause. *Cognitive Development, 19,* 111-125

Yamaguchi, M., Kuhlmeier, V.A., Wynn, K., & vanMarle, K. (2009). Continuity in social cognition from infancy to childhood. *Developmental Science, 12,* 746-752.

Young-Browne, G., Rosenfeld, H.M., & Horowitz, M. (1977). Infant Discrimination of Facial Expressions. *Child Development, 48(2),* 555-562

Figure Captions

Figure 1. Stimuli of facial emotional expressions used in both the Identification and Discrimination Tasks. The continuum end points represent the 100% Sad (Left) and 100% Happy (Right) faces. Each intermediate face differs from one another in increments of 10% of the entire range of faces.

Figure 2. Alternative preference score correlated with total from the Emotion Labels Questionnaire reported by the parent.

Figure 3. Alternative preference score correlated with the total number of words reported on the MDCI by the parent.

Figure 1.

Image 1 Image 2 Image 3 Image 4 Image 5 Image 6 Image 7 Image 8 Image 9 Image 10 Image 11

Figure 2.

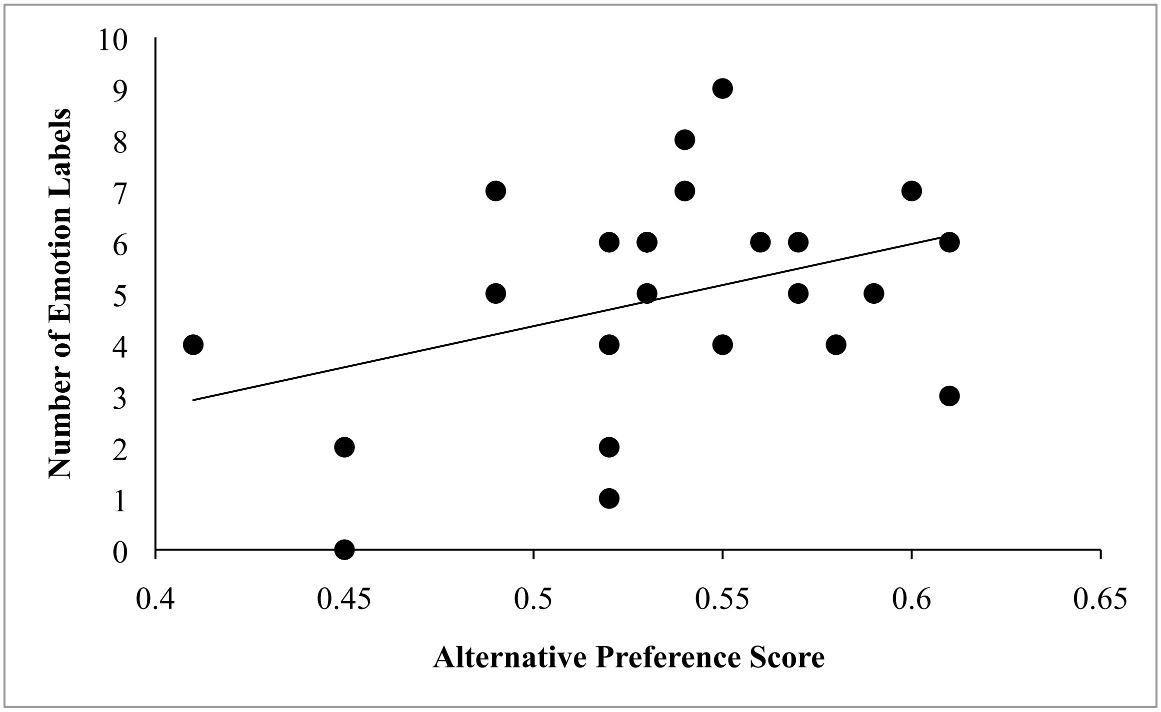
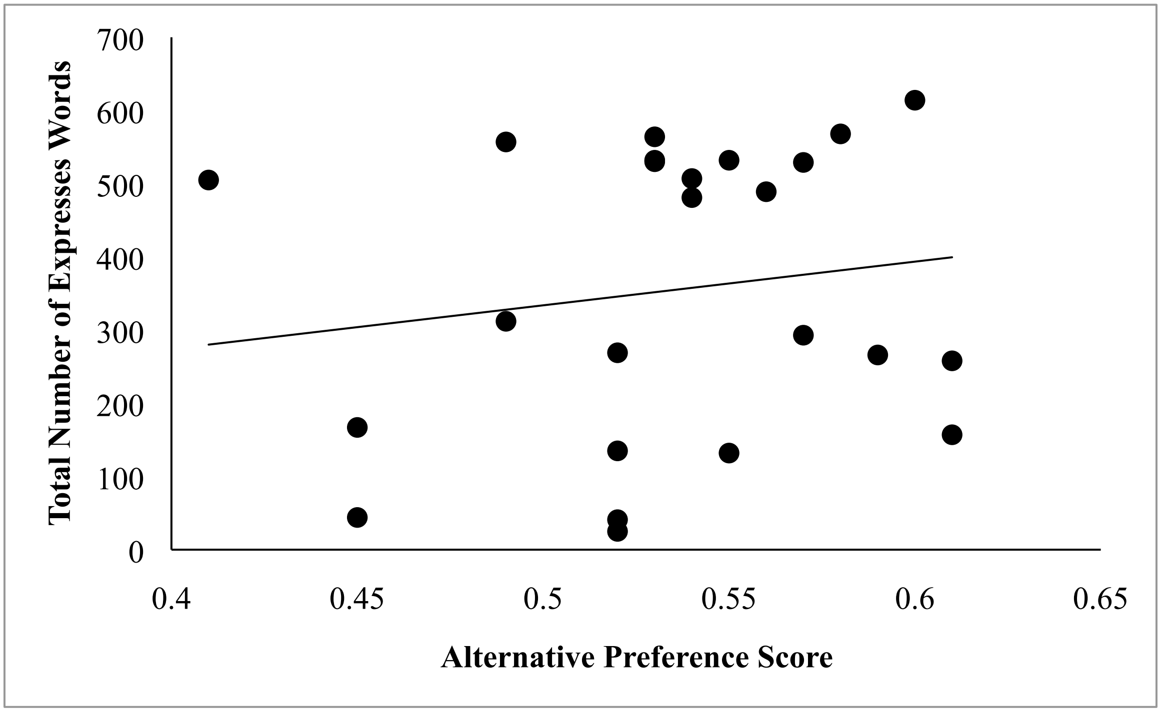

Number of Emotion Labels
10
9
8
7
6
5
4
3
2
1
0
0.4
0.45
0.5
0.55
0.6
0.65
Alternative Preference Score

Figure 3.


Total Number of Expresses Words
700
600
500
400
300
200
100
0
0.4
0.45
0.5
0.55
0.6
0.65
Alternative Preference Score

CHAPTER 5

CONCLUSION

Categorical perception is a psychological phenomenon by which continuous stimuli are perceived as discrete categories. Categorical perception is revealed when, controlling for physical differences between things, observers' ability to discriminate between categorically similar things is diminished, while between category differences are enhanced. This mechanism is an adaptive strategy because it allows for the quick and efficient categorization of information from the environment, and it allows for inferences to be made about members of each category. There inferences allow individuals to make predictions about the characteristics and actions of within and between group members, and this helps modulate their own responses. In adults, categorical perception has been studied in a number of domains including in phoneme discriminations (Liberman, Harris, Hoffman, & Grffith (1957); chord and harmony distinctions (Burns & Ward, 1978); along continuums of colour (Bornstein & Korda, 1984); and most importantly in facial emotional expressions (Etcoff & Magee, 1992; Calder et al., 1996).

Humans are skilled in understanding the emotion of others' simply by reading their facial expressions. The study of categorical perception of facial emotion expressions allows for a better understanding of how social information from faces organized and processed. Studies have demonstrated that categorical perception of facial emotion expressions occurs for most emotions in adults (Etcoff & Magee, 1992; Calder et al., 1996; Capanella et al; 2002), but the developmental trajectory defining categorical perception in facial emotional expressions is poorly understood.

In three empirical studies, this thesis investigated several aspects of the development of the perception of facial emotional expressions. Prior to these studies, there had been limited research into the development of categorical perception of facial expressions from infancy into early childhood. Specifically, it was unclear whether categorical perception of facial expressions developed simultaneously for all emotions, or whether there was a developmental relation between emotion perception and other aspects of emotion development, such as verbally naming emotions. Additionally, the relation between early social perception and later social skills was poorly understood.

Categorical perception of facial emotional expressions

In Chapter 2, I reported results from two experiments using looking-time based habituation paradigms showing that infants aged 6-, 9-, and 12-months were unable to categorically perceive faces along a happy-sad continuum. Infants from across the three age groups did not dishabituate to a novel face from across the category boundary. In contrast, 9- and 12-month-old infants, but not 6-month-olds, showed evidence of categorical perception when viewing facial emotional expressions along a happy-angry continuum. In Experiment 1, infants aged 6-, 9-, and 12-months were habituated to faces from *on either side* of a happy-sad (e.g. either a sad or a happy face) category boundary. Results demonstrated that infants across all three age groups did not dishabituate when tested with a novel face from across the category boundary, which we interpreted as failing the first criteria of categorical perception: the inability to better discriminate *between* category stimuli. In Experiment 2, 9- and 12-month-olds were habituated to faces *on either side* of a happy-angry (e.g. either a happy or angry face) category boundary. Results indicated that infants in both age groups dishabituated to a novel face from across the category boundary. Finally, 9- and 12-month-olds were tested on their ability to dishabituate to faces from *within* a category (e.g. just happy faces or angry faces). Results indicated that infants in both age groups did not discriminate between within category faces. Together, Experiment 2 demonstrated that infants at 9- and 12-months met criteria for categorical perception along the happy-angry continuum: better discrimination for *between* category stimuli, and diminished discrimination of *within* category stimuli. This study demonstrated that categorical perception does not develop uniformly between emotion pairs and age groups. We argued that the relevance of a particular facial expression to a child during a certain stage in development might influence the development of categorical perception.

This chapter expanded on the current research in categorical perception in infants and contributed to the literature in several ways. First, it was the first study to use looking-time habituation-based paradigm to test categorical perception along a happy-angry continuum. Our findings suggest that categorical perception along this continuum begins by at least 9-months of age. Second, the study demonstrated that infants before 12-months of age failed to categorize expressions along the happy-sad continuum. Third, this study was the first to use stimuli from the NimStim set to create a graduated continuum of stimuli, and together with results from other studies of categorical perception in infants (Kotsoni, de Hann, & Johnson, 2001; Leppanen et al., 2009; Cheal & Rutherford, 2010) demonstrate the generalizability of categorical perception across stimulus sets. Finally, this study was the first to systematically document categorical perception along the happy-sad and happy-angry continuum in 6-, 9-, and 12-month olds using the same stimuli and test procedures.

Categorical perception of facial emotional expressions in toddlers

In Chapter 3, I showed that toddlers aged 26-months use categorical perception when viewing faces along a happy-sad continuum. This study was the first to measure categorical perception using a paradigm tailored to testing toddlers. This experiment used novel tasks measuring both identification and discrimination that were modified for testing toddlers. These novel measures allowed me to determine that 26-month-olds use categorical perception when viewing faces along the happy-sad continuum, as adults do. Chapter 2 had demonstrated that infants at 12-months failed to categorically perceive faces along the happy-sad continuum, whereas a previous study showed that toddlers at 3.5 years of age could (Cheal & Rutherford, 2010). Together, these three studies help us to discern the developmental trajectory of categorical perception along the happy-sad continuum. Specifically, they suggest that categorical perception along the happy-sad continuum develops between 12-months and 26-months of age, and reach adult like accuracy at least by 3.5 years.

This chapter contributed to the literature by introducing a novel method to test categorical perception in toddlers. Previous studies looked at categorical perception using looking-time based paradigms (Kotoni et al, 2002) and ERP recording (Lepparen et al, 2006) in infants. Cheal and Rutherford (2010) modified the discrimination and identification tasks into verbal-based games for older toddlers. But this is the first study to utilize both a perceptual task and a game-based pointing task, to test for discrimination and identification, respectively, that worked well with toddlers. In adults, it is typical that the discrimination task precedes the identification task. The rationale is that discrimination tasks do not require verbal labeling that would influence category classifications while the other order could lead to carry-over effects from categorization by labels to discrimination. Here, we mimicked this sequence of procedures as closely as possible and ensured that the procedure for toddlers is logically equivalent to the test of categorical perception in adults. Specifically, toddlers start with a perceptual task that tests their ability to discriminate between a 100% happy face and all other intermediates within the continuum. Second, toddlers were tasked with identifying faces using the two category labels from the continuum. Finally, this study also demonstrated that by 26-months, children perceive faces categorically along a happy-sad continuum, similar to 3.5-year olds and adults.

Relation between early social perception and later social skills

Chapter 4 results suggest that perceptual sensitivity to changes in facial emotional expressions using a measure of looking-time may be related to having more emotion words in 26-month-olds. In this study, a larger vocabulary was a proxy to measure the amount of emotion labeling that occurred in parent-child interactions. Toddlers were familiarized with a happy face that anchored the continuum. During test, the happy face was paired with all other faces within the sad category. Attention to the "novel" faces (e.g. sad faces) was measured using looking-time. The proportion of looking-time to the novel face was significantly correlated with vocabulary size for emotional words. Preference for the novel faces was not significantly correlated with overall vocabulary size. This is an important distinction because it suggests this relationship may be specific to emotion labels and not a larger vocabulary in general.

This chapter adds to the current literature because it is the first study to link early social perception (sensitivity to changes in facial emotional expressions) and a social cognitive skill (vocabulary size for emotion words). Previous studies have demonstrated that early attention to faces is related to attachment styles (Peltola et al., 2015). Second, this study also suggests that parent-child interactions in talking about emotions and labeling emotions during toddlerhood may influence discriminability of facial emotional expressions, at least in happy and sad faces.

Collectively, these three studies indicate that categorical perception of facial emotional expressions has a long developmental trajectory across infancy and into childhood, and environment input may influence discrimination across categories. In part, this may be influenced by the increase in sensitivity to less intense emotions into early childhood (e.g. 5 years and above) (Gao & Maurer, 2010). Chapter 1 and Chapter 2 demonstrated that categorical perception along the happy-sad continuum develops well into toddlerhood. In contrast, Chapter 1 indicates that categorical perception along the happy-angry continuum develops during the first year of life. Together, these studies suggest that categorical perception of facial emotions is stratified and does not occur concurrently for all emotions. Further, we hypothesize that categorical perception may develop earlier for emotions that are more ecologically relevant to the child and perhaps adhere to the negativity bias (Vaish, Tobias, Woodward, 2008). Finally, Chapter 3 demonstrates that environmental input, such as learning about emotion labels, may influence perceptual discrimination of *between* category facial emotional expressions; suggesting cross domain relations in learning about emotions.

General Limitations

Stimuli

One particular limitation that impacts all the studies within this thesis is the use of images from the NimStim (Tottenham et al., 2009) stimulus set. Images from NimStim were chosen because they included a range of photo quality static images of different actresses performing different emotions including: happy, sad, and angry. Importantly, pictures included closed mouthed examples of each emotion, which helped simplify the morphing procedure for each continuum; previous studies found issues in morphing pictures with opened mouth examples showing teeth that affected categorical perception in adults (Calder et al. 1996). Images of females were used because expressions are often more accurately recognized from females than from male actors (Palmero & Coltheart, 2004), especially in expressions of anger and sadness. The use of the NimStim stimulus set in my studies was in contrast to previous studies of categorical perception that tended to use images from the Ekman and Friesen (1976) *Pictures of Facial Affect* stimuli set (Etcoff & Magee, 1992; Calder et al, 1996; Kotsoni, de Haan, Johnson, 2001; Cheal & Rutherford, 2010). The use of the NimStim limits the ability to compare results from my studies with other published works investigating categorical perception of facial emotions in adults and infants because contrasts between findings may be a result of the stimulus alone and not the experimental procedure. However, a potential problem of continually using the same stimuli set is that results obtained may not be generalizable. Therefore, even though using a novel stimulus set limits my ability to make comparisons with previous work, demonstrating categorical perception using NimStim strengthens the ability to generalize results about facial emotional expressions.

Another potential problem across all studies was that only one model was used to create the different continua within each experiment. Multiple models are often used to counteract the possibility that infants simply pay attention to the physical differences in faces and not the emotion itself. To overcome these issues, experiments often use 2 models (model A and model B) to create the same continuum (i.e. happy-sad), and each continuum is tested in a between-subject designs. If results are similar for both continua, then categorical perception of the *emotional* information rather than the *physical* information in faces is inferred. Although each of the studies in this thesis only used a single model, it should be noted that the models used to create the continuums differed across the chapters. The happy-sad and happy-angry continua in Chapter 1 was created using Model 7, whereas the happy-sad continuum in Chapter 2 and Chapter 3 was created using Model 1. Because there is evidence for categorical perception across the chapters using different models, it can be argued that emotional information was likely being used to process categorical information rather than merely the physical attributes of the faces.

My studies used a limited selection of continua. In previous work with adults, categorical perception of emotional facial expressions has been established for most basic expressions (Etcoff & Magee, 1992; Calder et al., 1996). In the previous developmental literature, 7-month-olds tested for categorical perception along the happy-fear continuum showed mixed results (Kotsoni et al., 2006), whereas 12-month-olds showed evidence of discrimination for between-, but not within-category, face pairs along a happy-sad continuum using measures of ERPs (Leppanen et al, 2009). Preschoolers at 3.5 years of age used categorical perception along a happy-sad continuum (Cheal & Rutherford, 2011). In Chapter 2 and Chapter 3, we tested categorical perception along the happy-sad continuum, which builds on previous literature using these emotions. Chapter 2 explored categorical perception in a new continuum using happy and angry faces. It is possible that different continua and models representing other pairs of expressions may yield different results.

More generally, the use of static images of expressions is also potentially problematic in that infants and children may be relying on a particular strategy for making judgments on identification and discrimination, and not the emotion represented by the face. Most studies of discrimination and identification of facial emotional expressions have used static images as stimuli. But recent evidence suggests that infants may use different cues for 3D dynamic models, drawing into question if findings from studies using static images can be generalized to real-life scenarios (Xiao, Perrotta, Quinn, Wang, Sun, & Lee, 2014; Heck, Hock, White, Jubran, & Bhatt, 2016). Xiao et al. (2014) found that the ability to differentiate anger in dynamic faces changes between 3.5- and 5-month-olds infants, a finding that has the potential to change interpretation of previous findings using static faces. It is possible that investigating categorical perception using dynamic stimuli may yield different results across emotions and age groups.

Procedure

In Chapter 2, the physical differences between intermediate faces within the 2 continua (happy-sad and happy-angry) were larger than typically used in adult studies investigating categorical perception of facial emotions. In this study, the physical difference between faces was 33% (creating a 4-face continuum) instead of 20% (6 -face continuum), or 10% (11-face continuum). While it would have been desirable to use comparable intermediates to adult studies, pilot data with 6- and 9-month-olds revealed that infants were unable to dishabituate to faces across a happy-sad or happy-angry category boundary with such small physical differences (20% or 10% differences) between adjacent images. The reason for increasing the physical difference between intermediate faces was to determine whether a larger change across the boundary would elicit better discrimination. Here, I found that categorical perception occurred only in the happy-angry continuum for 9- and 12-month-old infants but not 6-month-olds. I did not find categorical perception along the happy-sad continuum even with a larger difference between intermediates (i.e. 33%) when compared to stimuli from adult studies. The results should be interpreted with some caution because an increase in the physical difference between intermediate faces lessens a direct comparison to adult results and therefore limits a strong claim for categorical perception. Yet, the increase in physical difference between adjacent images does not change the logic of using results from discrimination and identification tasks as evidence for categorical perception or the interpretation of our results for the happy-sad continuum.

Correlation Analysis

In Chapter 4, I found a relationship between toddlers' ability to visually discriminate between happy and sad facial emotional expressions and the number of emotion labels used, as reported by their parents. A correlation analysis conducted using visual discrimination of happy and sad faces and the toddlers' overall vocabulary size yielded non-significant results. These results would support a hypothesis that toddlers' reliance on emotion labels aids in their visual discriminative abilities, or visa versa. However, these results should be interpreted with caution considering a number of limitations. First, the number of items on the emotion labels questionnaire was considerably smaller than the number of item on the overall vocabulary checklist (MCDI). This unequal pairing of items could have resulted in biased reporting by the parents. Specifically, it may be possible that parents over reported the number of emotion labels used or under reported (i.e., more conservative) the overall number of words used on the MCDI. Another limitation was that our sample size was quite small ($n = 23$). Typically, correlation studies using a power level of 0.80 and a α of 0.05 requires at least 28 participants for a large effect size. Our non-significant correlation between visual discrimination of facial expressions and overall vocabulary size could simply be a result of low power.

Future Directions

Categorical perception of facial emotional expressions in infants and toddlers

In Chapter 2 and 3, I investigated categorical perception of facial emotional expressions across the first year of life and in 2.5 year-olds. The results suggest that infants younger than 12-months of age do not use categorical perception along a happy-sad continuum. Yet, Chapter 3 suggests that categorical perception occurs for the happy-sad continuum by 2.5 years of age. There is a considerable gap between the evidence of when categorical perception along the happy-sad continuum does not occur and when it seemingly emerges later in toddlerhood. Future studies could investigate the precise age at which categorical perception along the happy-sad continuum is manifest. It should be noted, however, that the continuum used to detect categorical perception were different between Chapter 2 and Chapter 3. Chapter 2 used a modified continuum in which the physical differences between intermediate faces was 33% whereas in Chapter 3 the continuum of faces differed by 20% each. Using both these continua to test infants and toddlers between 12-months and 2.5 years of age, we could potentially detect when categorical perception may first emerge in infants using the modified continuum (Chapter 2) and when categorical perception becomes adult-like using the continuum from Chapter 3. Even so, I would not expect categorical perception along the happy-sad continuum to occur earlier than 12 months even with smaller (finer) differences between stimuli.

Another area of future research would be to systematically vary the pairs of emotions used to create continua and to test categorical perception along all continua across the first year of life and into toddlerhood. Research investigating the developmental trajectory of categorical perception is limited. Additionally, we only have developmental evidence to support categorical perception along a limited number of continua (i.e. happy-sad, happy-angry, and happy-fear). It would be important to continue exploring categorical perception along various continua to gain a fuller understanding of the development of this cognitive phenomenon. As suggested in this thesis, categorical perception does not develop simultaneously for all emotions and continua, and it would be essential to continue exploring how the combination of predisposition and environmental inputs influence its development.

Future studies could also explore how the consequences of different environmental circumstances influence the perception of category boundaries in infants and toddlers. Previous research suggests that early exposure to negative environments (Pollack & Kistler, 2002) alters the perception of facial emotional expressions along a continuum in school-aged children, such that there is a slight bias towards categorizing emotions as more negative. It is important to investigate whether other environmental circumstances influence perception. For example, infants in the care of mothers who experience postpartum depression may also show a bias towards more negative emotions because of an increased exposure to neutral or negative facial emotional expressions. It is also important to investigate the frequency and intensity of exposure that might influence the bias. It would also be interesting to test whether there is sensitive period for inducing a bias towards negative emotions and whether interventions early in development can correct the bias towards more negative emotions in categorical perception.

Finally, Chapter 4 focused on the relation between sensitivity to changes in emotion stimuli that span the category boundaries and the use of emotional labels in preschool children. Researchers in social perception speculate that mechanisms that guide attention and perception of social information benefit the development of social cognitive skills. Attention and perception of facial emotional expressions helps humans learn from social others and gather social information. It is important for future research to continue investigating the relation between early social perceptual skills and later social cognitive abilities. For example, it would be interesting to study how sensitivity to changes in facial emotional expressions might be related to the development of empathy or prosocial behaviour in preschool children.

Conclusions

In this thesis, I examined the developmental trajectory of categorical perception of facial emotional expressions. Additionally, I investigated the relation between sensitivity to changes in facial emotional expressions and labeling using emotional words. In Chapter 2, I found that infants before the first year of life did not show evidence of categorical perception along a happy-sad continuum. In contrast, 9- and 12-month-old infants, but not 6-month-old infants, could reliably categorize facial emotional expressions along a happy-angry continuum. Our findings suggest that categorical perception may not develop simultaneously for all emotions. It also suggests that experience with, and relevance of, certain emotions may be developmentally related to the use of categorical perception. Chapter 3 demonstrated that toddlers by the age of 2.5 years of age use categorical perception along a happy-sad continuum. This study provided the earliest evidence of categorical perception along the happy-sad continuum as measured by explicit behaviour (i.e. looking-time and pointing/ labeling). Chapter 4 demonstrated that may be a relation between the sensitivity in discriminating facial emotional expressions and labeling of emotions via parent-child interactions. The study ruminates on potential directions of this relation and how learning about emotions may require integration of information from across domains.

Humans rely on the ability to perceive and interpret emotional information from faces to successfully navigate the social world. Categorical perception is one strategy that simplifies social information, and allows for quick and efficient decisions to be made in response to expressions. The research described in this thesis advances our understanding of how humans begin to process and understand emotional information in their environment. These chapters add to our understanding of categorical perception of facial emotional expressions from a developmental perspective and add valuable information to the existing literature. Research in infants and toddlers is a contribution to the field because it adds to the limited literature and understanding of the developmental trajectory of categorical perception of facial emotional expressions. These studies have gone beyond previous research by testing new continua and using modified methodology for toddlers. In addition, it raises questions about the built-in processes and environmental input that influences the development of categorical perception of facial emotions. The research in linking the development of perception of facial emotional expressions and emotion labels adds to our understanding of the relation between perception and behaviour. This study is the first to suggest such a link between two domains and adds to our understanding of the building blocks for categorical perception across development. Finally, all three chapters suggest a long developmental trajectory for categorical perception of facial emotional expressions and expertise develops well into childhood.

References

Barrera, M. E. & Maurer, D. (1981). The perception of facial expressions by the three-month-old. Child Development, 52, 203-206.

Benson, P. J., & Perrett, D. I. (1991). Synthesising continuous-tone caricatures. *Image and vision computing*, *9*(2), 123-129.

Boone, R. T., & Cunningham, J. G. (1998). Children's decoding of emotion in expressive body movement: the development of cue attunement. Developmental psychology, 34(5), 1007.

Bornstein, M. H., & Korda, N. O. (1984). Discrimination and matching within and between hues measured by reaction times: Some implications for categorical perception and levels of information processing. *Psychological research*, *46*(3), 207-222.

Bornstein, M. H., & Monroe, M. D. (1980). Chromatic information processing: Rate depends on stimulus location in the category and psychological complexity. *Psychological Research*, *42*(3), 213-225.

Bornstein, M. H., Kessen, W., & Weisskopf, S. (1976). Color vision and hue categorization in young infants.Journal of Experimental Psychology: Human Perception and Performance, 1, 115–129.

Burns & Ward, 1978, Categorical perception-phenomenon or epiphenmenon: evidence from expeirments in the perception of melodic mustical intervals. J Acout Soc Am. 1978, 63: 456-468

Calder, A. J., Young, A.W., Perrett, D.I., Etcoff, N.F., & Rowland (1996). Categorical perception of morphed facial expressions. Visual Cognition, 3(2), 81- 117.

Campanella, S., Quinet, P., Bruyer, R., Crommelinck, M., & Guerit, J. M. (2002). Categorical perception of happiness and fear facial expressions: an ERP study. *Journal of cognitive neuroscience*, *14*(2), 210-227.

Cheal, J. L., & Rutherford, M. D. (2011). Categorical perception of emotional facial expressions in preschoolers. Journal of Experimental Child Psychology, 110, 434–443.

de Gelder, B., Teunisse, J. P., & Benson, P. J. (1997). Categorical perception of facial expressions: Categories and their internal structure. Cognition & Emotion, 11(1), 1-23.

Dunn, J., Brown, J., & Beardsall, L. (1991). Family talk about feeling states and children's later understanding of others' emotions. Developmental Psychology, 27(3), 448.

Ekman, P., & Friesen, W. V. (1976). Measuring facial movement.*Environmental psychology and nonverbal behavior*, *1*(1), 56-75.

Etcoff, N.L. & Magee, J.J. (1992). Categorical perception of facial expressions.Cognition, 44, 227-240.

Farroni, T., Menon, E., Rigato, S., & Johnson, M.H. (2007). The perception of facial expressions in newborns. European Journal of Developmental Psychology, 4(1), 2-13.

Gao, X., & Maurer, D. (2009). Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions. *Journal of experimental child psychology*, *102*(4), 503-521.

Gao, X., and Maurer, D. (2010). A happy story: Developmental changes in children's sensitivity to facial expressions of varying intensities. Journal of Experimental Child Psychology, 107(2), 67-86.

Goldstone, R. L., & Hendrickson, A. T. (2010). Categorical perception. *Wiley Interdisciplinary Reviews: Cognitive Science*, *1*(1), 69-78.

Harnad, S. (1987). Psychophysical and cognitive aspects of categorical perception : critical overview. In S. Harnad (Ed.), Categorical perception : The groundwork of cogntiion, (pp.1-25). New York : Cambridge University Press.

Heck, A., Hock, A., White, H., Jubran, R., & Bhatt, R. S. (2016). The development of attention to dynamic facial emotions. *Journal of experimental child psychology*, *147*, 100-110.

Johnson, Dziurawiec, Ellis, Morton, 1991. Newborns preferential tracking of face-like stimuli and its subsequent decline. Cognition

Kikutani, Robertson, & Hanley, 2008, What's in the name? Categorical perception for unfamiliar faces can occur through labeling. Psychon Bull Rev, 2008, 15:787-794

Kotsoni, E., de Haan, M., Johnson, M.H. (2001). Categorical perception of facial expressions by 7-month-old infants. Perception, 30, 1115-1125.

Lagattuta, K. H., & Wellman, H. M. (2002). Differences in early parent-child conversations about negative versus positive emotions: implications for the development of psychological understanding. *Developmental Psychology*,*38*(4), 564.

Leppänen, J.M., Richmond, J., Vogel-Farley, V.K. Moulson, M.C., & Nelson, C.A. (2009). Categorical representation of facial expressions in the infant brain. Infancy, 14, 346-362.

Liberman, Harris, Hoffman, & Griffith, 1957. The discrimination of speech sounds within and across phoneme boundaries. J. Exp. Psychol. 1957

Mondloch et al., 1999. Face perception during early infancy. *Psychological Science*. 10, 419-422

Newell, F. N., & Bülthoff, H. H. (2002). Categorical perception of familiar objects. *Cognition*, *85*(2), 113-143.

Palermo & Coltheart, 2004. Photographs of facial expressions: Accuracy, response time, and ratings of intensity. Behavior Research Methods, *Instruments & Computers, 36(4), 634-638*

Peltola, M. J., Forssman, L., Puura, K., IJzendoorn, M. H., & Leppänen, J. M. (2015). Attention to faces expressing negative emotion at 7 months predicts attachment security at 14 months. *Child development*, *86*(5), 1321-1332.

Phillips, A.T., Wellman, H.M., Spelke, E.S. (2002). Infants' ability to connect gaze and emotional expression to intentional actions. Cognition, 85, 53-78.

Pisoni, D. B., & Tash, J. (1974). Reaction times to comparisons within and across phonetic categories. *Perception & Psychophysics*, *15*(2), 285-290.

Pollack, S.D. & Kistler, D.J. (2002). Early experience is associated with the development of categorical representations for facial expressions of emotion. Proceedings of the National Academy of Science of The United States of America, 99(13), 9072-9076.

Repp, B.H. 1984. Categorical perception: Issues, methods, findings. Speech Lang Adv Basic Res Pract, 1984, 10:243-335

Rossion, Schiltz, Robaye, Pirenne, & Crommelinck (2001). How does the brain discriminate fdamiliar and unfamiliar faces?: a PET study of face categorical perception. J Cogn Neurosci 2001 13: 1019-1034

Saarni, C., & Harris, P. L. (1991). *Children's understanding of emotion*. CUP Archive.

Schwartz, G. M., Izard, C. E., & Ansul, S. E. (1985). The 5-month-old's ability to discriminate facial expressions of emotion. *Infant Behavior and Development*, *8*(1), 65-77.

Serrano, J. M., Iglesias, J., & Loeches, A. (1992). Visual discrimination and recognition of facial expressions of anger, fear, and surprise in 4- to 6-month-old infants. Developmental Psychobiology, 25, 411-425.

Studdert-Kennedy, M, Liberman, A.M., Harris, K.S., & Cooper, F.S. (1970). Theoretical notes. Motor theory of speech perception: A reply to lane's critical review. *Psychological Review, 77,* 234-249.

Studdert-Kennedy, M., Liberman, A. M., Harris, K. S., & Cooper, F. S. (1970). Motor theory of speech perception: A reply to Lane's critical review.

Tottenham, N., Tanak, J.W., Leon, A.C., McCarry, T., Nurse, M., Hare, T.A. et al. (2009). The NimStim set of facial expressions: Judgements from untrained research participants. Psychiatry Research, 168, 242-249.

Vaish, A., Grossman, T., and Woodward, A. (2008). Not All Emotions Are Created Equal: The Negativity Bias in Social-Emotional Development. Psychology Bulletin, 134 (3), 383-403.

Valenza, E., Simion, F., Cassia, V. M., & Umiltà, C. (1996). Face preference at birth. *Journal of experimental psychology: Human Perception and Performance*, *22*(4), 892.

Walker-Andrews, A. S., & Grolnick, W. (1983). Discrimination of vocal expressions by young infants. Infant Behavior and Development, 6(4), 491-498.

Xiao, N. G., Perrotta, S., Quinn, P. C., Wang, Z., Sun, Y. H. P., & Lee, K. (2014). On the facilitative effects of face motion on face recognition and its development. *Frontiers in psychology*, *5*, 633.

Young-Browne, G., Rosenfeld, H. M., & Horowitz, F. D. (1977). Infant discrimination of facial expressions. *Child Development*, 555-562.