EXAMINING CATEGORICAL PERCEPTION OF EXPRESSIONS

EXAMINING CATEGORICAL PERCEPTION OF EMOTIONAL FACIAL EXPRESSIONS

By

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Preface

This thesis comprises four manuscript chapters produced in collaboration with my supervisor, Dr. M.D. Rutherford. I was directly responsible for the experimental design, and the collection, analysis, and interpretation of all the data for all the experiments reported. Chapter 2 is a manuscript that has been submitted for publication to the journal *Emotion*. Chapter 3 is a manuscript currently submitted for publication in *Cognition & Emotion*. Chapter 4 is a manuscript that has been invited for revision in the *Journal of Experimental Child Psychology*. Chapter 5 is a manuscript that has been accepted for publication in *Perception* and is currently in press. I was responsible for the preparation of all four manuscripts.

Abstract

Individuals perceive emotional facial expressions in categories. Specifically, for basic emotional expressions, discrimination performance is better for pairs of stimuli that fall on either side of a perceptual category boundary than for those within a perceptual category. In this thesis I have examined categorical perception of emotional facial expressions from a number of different perspectives. In Chapter 2, I found in two experiments that categorical perception of emotional facial expressions is a robust phenomenon with a few consistent individual differences. These findings highlight some of the important caveats that categorical perception researchers face, not only in the area of emotional facial expressions, but across domains as well. In Chapter 3 I show that context has an effect on the visual perception of emotional facial expressions. A surprise-fear continuum was perceived categorically only in the case in which a context story was provided for the surprise face. In Chapter 4 I demonstrate categorical perception for a happy-sad continuum in 3.5-year-olds. This is an important study in development because the current literature is limited by studies that do not compare identification and discrimination performance in these age groups. The experiment in this chapter uses both identification and discrimination tasks and compares the results of 3.5-year-olds to adults who do the exact same task. The results suggest that 3.5-year-olds perceive happy and sad expressions as adults do, categorically. In Chapter 5 I develop a powerful new methodology for the study of the category boundary using non-verbal methods. This investigation with

emotional facial expressions shows it can be reliably used to identify category boundary information in adults. Perception of emotional facial expressions is an essential part of successful social cognition, and the phenomenon of categorical perception specifically allows individuals to quickly and accurately respond to expressions. The research in this thesis is a further step in understanding the processes that allows individuals to be successful in a social environment.

Acknowledgements

I would first like to thank my supervisor, Dr. Mel Rutherford, for his guidance and support during my time as a graduate student. Sometimes my fear that you were going to ask me about my next manuscript was the only thing that motivated me to keep working on it. I would also like to thank the members of my supervisory committee, Daphne Maurer, Judith Shedden, and Allison Sekuler, for their support. I would also like thank the members of the Rutherford Lab who all, at one time or another, helped me with various aspects of my project. To the graduate students in my lab, Paul, Marla, Jenn, and Vivian, thank you for your constructive criticism and for making my time at McMaster fun.

To my parents, Candace and Cameron, I am indebted to you first for your generosity, but also for your constant encouragement and support. You have always been there for me, whether it was allowing me to splurge on a trip I could not afford, or being just a phone call away when I needed to hear your voice. To my sisters, Lauren and Taryn, thank you for being my constant source of fun. Laur, I would never have learned to use a comma without your editing skills.

Thank you to my friends outside of academia. To the members of the Dundas Concert Band, thank you for providing such a friendly outlet for me to play and enjoy music—the break from school was much-needed and appreciated. In particular, to my friend Donna, for listening to my stories about my cats and making me laugh at least once during every rehearsal. To the members of DS, your intelligent (and sometimes not-so-intelligent) conversation has always been a great way to debate ideas and get many differing viewpoints.

Finally, to my partner Ash, thank you for supporting me through this journey. You left a job you loved and moved from your family and friends to be with me. I would have been lost without your love and support here.

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CHAPTER 1

INTRODUCTION

Categorization is essential to human and non-human perception and cognition, allowing individuals to parse the world into meaningful pieces of information. Categories are mentally represented collections of entities. They can be broad, such as the category of "animals", where great variety is seen between individual members of the category, or very narrow, such as the category of "miniature poodles". Categories are important because they allow easy comparison of items and may facilitate communication about those items (Harnad, 1987a). In addition, categories allow for inference (Pinker, 1997). We are able to quickly assess situations and stimuli we have never experienced, helping us navigate the social world.

As stated above, categories can range from broad to specific. They can also be conscious or unconscious. For example, categorization of auditory signals into discrete and varying sounds can be an automatic process. Categories can also be natural or artificial: natural categories, or natural kinds, are groups of entities that reflect intuitive distinctions in the world, such as the difference between living and non-living. Natural kinds are contrasted with artificial categorizations which are arbitrary and might rely on individual judgment or historical precedence. The organization of land into political states is one such example. Regardless of the origin or type of category, categories are useful because they help solve the problem of segmenting information into useful pieces of information.

1.1 Categorical Perception

In contrast to the subjective placement of items into categories, categorical perception, by convention, is a psychological phenomenon for which specific conditions must be met. These conditions are measurable in a controlled laboratory environment and reveal the difference between the physical world and perception of it. Typically a definition, such as the following, is used as a criterion for inferring categorical perception. "In [categorical perception] 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). This definition allows for perception of within category differences but requires enhanced discrimination of items that are drawn from separate categories. Pastore (1987) further suggests that the concept of categorical perception be refined to be called categorical perception only when perception falls under the strict definition and suggests that the more lenient "category boundary effects" be used when discrimination of within category items is still possible. A strict definition of categorical perception would suggest that an individual would perceive all members of a particular category as exactly the same with no detection of changes occurring within a category. One example of this kind of strict definition is given by Studdert-Kennedy, Liberman, Harris, and

Cooper (1970), "Categorical perception refers to a mode by which stimuli are responded to, and can only be responded to, *in absolute terms*" (Studdert-Kennedy, et al., 1970, p.234). This ideal is rarely found in the laboratory, even when stimuli are perceived categorically individuals can often still detect differences occurring within category. However, for the purposes of this thesis and because it is standard in the literature a claim of categorical perception will refer to a definition that allows for discrimination within category but requires more accurate discrimination for between category comparisons.

1.2 Research Standards for Categorical Perception

Psychological distance can be measured in a number of different ways, including the reaction time necessary to distinguish two stimuli, the accuracy with which they are discriminated, and the explicit similarity reported by the participant (Repp, 1984). The psychophysical responses given to stimuli in a number of domains suggest that at the perceptual level, these stimuli are being grouped (Harnad, 1987a). That is to say, the percept is not predicted simply by physical similarity. A number of different domains have been identified for which categorical perception occurs. These include speech sounds (Eimas, 1963; Liberman, Harris, Hoffman, & Griffith, 1957), colors (Bornstein & Korda, 1984), emotional facial expressions (Calder, Young, Perrett, Etcoff, & Rowland, 1996; Etcoff & Magee, 1992), and vocal emotional expressions (Laukka, 2005).

Typically, categorical perception is investigated by studying the perception of a continuum of stimuli that are equally physically distant from one another and span a category boundary. Participants perform two tasks: an identification task and a discrimination task. The identification task can be a free naming task, in which stimuli are presented and participants give their own identification categories or as is more typical, the stimuli can be presented in the format of a 2-alternative-forced-choice (2AFC) experimental paradigm. In the latter case participants are supplied with the two category labels that best describe the endpoints of the continuum, and are required to respond with one of the two labels. In a free response paradigm, participants tend to classify stimuli as one of the two exemplar categories, even when the stimulus is intermediate (Etcoff & Magee, 1992).

The second task is a discrimination task. The discrimination task results in accuracy scores when participants discriminate the pairs of stimuli from the same continuum used in the identification task. A common way to test discrimination performance is through matching tasks. For example, the ABX matching task requires participants to compare two sequentially presented images (image A and B) and determine which of the first two matches a third image (image X) (Calder et al., 1996; Etcoff & Magee, 1992; Repp, 1984). Another way to assess discriminability is a matching task in which two of the stimuli are displayed at the same time and the participant makes a decision of same or different (Calder, et al., 1996).

Using the information from the identification and discrimination tasks together, categorical perception can be inferred if the following conditions are met

(Harnad, 1987a; Repp, 1984; Studdert-Kennedy, Liberman, Harris, & Cooper, 1970): from the identification data response, curves are graphed such that the points along the continuum are represented on the x-axis and percent response on the y- axis. If the continuum is perceived categorically, it is expected that the curve will be "s-shaped", such that the slope changes from one category distinction to another rapidly. The point of maximal slope is the 50% identification point (Repp, 1984; Studdert-Kennedy et al., 1970), the point at which stimuli are maximally ambiguous. This point is likely to be the category boundary. The 50% identification point is then compared to the discrimination accuracy performance. If the peak in performance in the discrimination task occurs at the same location as the 50% point in the identification task, this is taken as strong evidence of categorical perception as well as evidence that the categorical boundary has been identified (Repp, 1984). This peak reflects the fact that it is easier to perceive stimulus differences when they cross a perceptual category compared to stimuli discriminations with the same physical distance that are within a category.

Some authors have also used reaction time to support their claims of categorical perception by looking at changes in reaction times across the continuum in the identification task (Bornstein & Korda, 1984; de Gelder, Teunisse, & Benson, 1997). Participants are fastest at identifying stimuli when they are furthest away from the category boundary and closer to a prototypical instance of the category. In addition, participants are fastest at discriminating two stimuli when they cross a category boundary than when the discrimination is within category. This reaction time finding mirrors that of accuracy performance.

1.3 Historical Background of Categorical Perception Research

Categorical perception was first identified in the area of speech perception. Liberman, Harris, Hoffman, and Griffith (1957) used an artificial speech synthesizer to vary voice onset time and create continua of speech sounds that could be tested for identification and discrimination. This early study examined three consonant sounds followed by a vowel, /e/. They used both identification and ABX discrimination tasks to show categorical perception of these speech sounds and to set the standard for methodology for future research in the same area.

Throughout the 1960s, investigations into categorical perception continued within the domain of speech sounds, where researchers broadened the findings to include other consonants, but did not find reliable evidence for categorical perception of isolated vowel sounds (e.g., Eimas, 1963; Liberman, Harris, Kinney, & Lane, 1961). In the 1970s more groups began to study categorical perception of speech and important theories about the nature and circumstances of categorical perception emerged. The *motor theory of speech perception* suggests that speech perception is a direct reflection of the types of articulation that individuals can produce (Studdert-Kennedy, Liberman, Harris, & Cooper, 1970). The *dual-process model* for discriminating speech stimuli suggests there are two contributors to speech discrimination: one that is associated with rapid discrimination of a stimulus sound based on the phonetic properties of the stimulus and another that includes all processes of auditory perception (Pisoni & Lazarus, 1974). This model aimed to account for findings that discrimination was possible for within category stimuli. In the mid-1970s researchers took a closer look at categorical perception using psychophysics (Macmillan, Kaplan, & Creelman, 1977). The result of these investigations was a *single-process model* that relied on properties of the auditory system (and the thresholds of stimuli) to explain categorical perception rather than on properties of speech (as in the dual-process model) (see Repp, 1984 for review).

Research on categorical perception continued to expand during the 1970s and 1980s. Infant speech perception was found to be similar to that of adults for some speech stimuli (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). Infant speech was found to be segmented, like that of adults into categories probably based on syllables including a consonant and vowel (Eimas, Miller, & Jusczyk, 1987). Others included animals in studies of speech perception and have found that some animals separate speech sounds similarly to typical adults (Kuhl & Miller, 1975). In addition to this branching of speech research, categorical perception was used to explain color categories both in infants and adults (Bornstein, 1987; Bornstein & Korda, 1984).

Findings of categorical perception were further broadened starting in the early 1990s. In 1992 Etcoff and Magee found the first evidence of categorical perception of emotional facial expressions using morphed line drawings of emotional faces. Several authors replicated and extended these findings (e.g., Calder, Young, Perrett, Etcoff, & Rowland, 1996; de Gelder, Teunisse, & Benson, 1997; Suzuki, Shibui, & Shigamasu, 2008; Young et al., 1997) [For a complete review of categorical perception of emotional facial expressions see Section V]. Categorical perception has even been found for discriminations between vocal emotional expressions (Laukka, 2005).

1.4 Face Perception and Social Cognition

Faces are among the most important sources of social information. Broad categorical information, such as age, sex, and race, can be gleaned from a brief view of face so quickly it is said to be automatic (Allport, 1954). A wealth of other information can also be gained from looking at a face, including identity and emotion. Several lines of evidence suggest that faces are a special class of stimuli that may have privileged processing compared to other visual stimuli we encounter. Young infants look preferentially at faces over other similarly complex objects (Johnson, Dziurawiec, Ellis, & Morton, 1991) and adults have brain areas specific to the processing of faces (McCarthy, Puce, Gore, & Allison, 1997).

Emotional expressions convey important social information. Certain emotional expressions (happy, sad, fear, anger, disgust, and surprise) have been considered 'basic' because they are distinguished cross-culturally and have specific associated patterns of muscle movement required to produce them (Ekman, 1994). Perception of facial expressions matures quickly over the first two years of life. Infants younger than 2 months of age show little evidence of being able to discriminate emotional facial expressions however, around 2-3 months of age infants begin to show evidence that they can discriminate among emotional facial expressions (Nelson, 1987). Beyond the first year and into the second year of life, recognition and discrimination of emotional facial expressions improves with increasing age until it appears adult-like in the teens (Batty & Taylor, 2006).

In Darwin's 1872 book, "The Expression of the Emotions in Man and Animals" it was recognized that emotion perception played an important role in social cognition, or knowing information about others' internal states and motivations for behavior. In its truest form, categorical perception describes a phenomenon in which an individual shows less acute ability to discriminate items that are within categories, but are nonetheless good at discriminating two exemplars that are the same distance apart but span a category boundary (Harnad, 1987a; Repp, 1984). It is suggested that this type of perception is functional; it allows us to make quick judgments about category membership and presumably, act more quickly as a result (Harnad, 1987b). In the case of emotional facial expressions, individuals would be able to make decisions of approach and avoidance more quickly. In the environment of evolutionary adaptedness (EEA) making quick decisions about approach and avoidance of individuals would have been beneficial while making slow decisions could lead to costly mistakes (Cosmides & Tooby, 2000; Nesse, 1990).

Evidence that individuals modify their behavior in response to emotional cues comes from several sources. Adults identify faces displaying fear and anger faster and more accurately than those displaying other emotions or neutral expressions (Öhman, Lundqvist, & Esteves, 2001). Emotions can be processed quickly and without conscious awareness (Morris, Öhman, & Dolan, 1998). A large body of social referencing literature provides clear evidence that the perception of emotional facial expressions is functional for infants, and that they have an effect on infant behavior. By 1 year of age infants modify their behavior (they cross or refuse to cross a visual cliff) in response to posed expressions (joy or fear, respectively) from the mother (Sorce, Emde, Campos, & Klinnert, 1985). Even non-human primates have been shown to modify their behavior in response to facial expressions, such as monkeys who had been raised in isolation showing fear reactions when presented with threatening faces (Sackett, 1966).

1.5 Categorical Perception and Emotional Facial Expressions

Etcoff and Magee (1992) used converging evidence from an identification task and a discrimination task, as described above, in the first demonstration that emotional facial expressions are perceived categorically. Participants performed an identification task and a discrimination task using line drawings of a continuum of physically equidistant facial expressions. Discrimination was more accurate between facial expressions when the two images fell on either side of the category boundary than when the two drawings were from within the same category – even when these drawings were physically different by the same amount. The authors suggest that there is a functional aspect to this particular perceptual categorization. If individuals are specialized for detecting the emotional states of others, this mechanism may allow us to efficiently determine others' emotional states and therefore plan our own behavioural response accordingly.

Subsequently, other studies have investigated categorical perception in emotional facial expressions. Calder et al. (1996) improved upon these methods by using morphed photographs rather than line drawings to investigate this phenomenon. Using these more naturalistic stimuli, Calder et al. were able to replicate the findings of Etcoff and Magee (1992) and agreed that emotional facial expressions are perceived categorically. In addition, they ruled out effects of working memory on the task by decreasing the amount of information that needed to be held in memory to complete the task. To reduce memory demands, the authors implemented a "same" or "different" approach to the discrimination task. The results obtained from this task mirrored those of the original discrimination task. Those images within a category were more difficult to discriminate than those that straddled a category boundary, even when the physical distance between these images was equal.

Other authors have since investigated categorical perception of emotional facial expressions using photographs but have extended the findings to all pairings of the six basic emotions (happy, sad, anger, disgust, fear, surprise) (Young et al., 1997) and have investigated how inversion affects categorical perception (de Gelder et al., 1997). De Gelder et al. (1997) determined that categorical perception was reduced by inversion, concluding that the relevant information of categorical perception may be configural in nature, as it is known that inversion disrupts configural processing (Valentine, 1988).

1.6 The Current Research

Each of the studies included in this thesis uses morphed stimuli created from the Ekman & Friesen (1976) *Pictures of Facial Affect* stimulus set. While some criticism has been levied against these images in recent years, they were used for several specific reasons and the benefits of this stimulus set was thought to outweigh the problems that might be associated with them. First, the current studies attempted to extend previous findings of categorical perceptions of emotional facial expressions. To that end I relied on comparison to previously published and varied data. Most previous studies (e.g., Calder, et al., 1996; Etcoff & Magee, 1992) have used this stimulus set and therefore my using the same set minimizes some of the error that occurs when comparing results from different stimuli. The Ekman & Friesen faces have been used in numerous other studies of face perception. Again, this allows for greater ease of comparison between previously published work and the current investigation and it suggests these faces are recognized as appropriate stimuli to be used in studying emotion perception. The images in this set were all taken under standard lighting conditions and have existing reliability data. Finally, independent testing of the face set means that we can use this information to help interpret results. Palermo and Coltheart (2004) how accurate participants were at identifying the emotion supposedly displayed by a face as well as the subjective intensity of a given face. This information is not available on new face sets and has proved invaluable.

Each of the following studies used images of expressions that had been morphed, or digitally transformed, from one expression image to another. The goal of this procedure is the creation of intermediate expression images that vary in consistent and measureable physical increments and thus can be used to study categorical perception. The morphed images used in this thesis were created using a commercially available morphing program, Morpheus v.1.85. This software, like many other available morphing packages, combines two images to create a continuum from one image to another that is consistently varied. The software requires the user to identify matching points on both images and then morphs one image to the other in two phases. In one phase the images are warped toward each other, such that the shapes of each image are preserved. In the second phase the pixel by pixel color values are combined resulting in average color information at each pixel location. The resulting intermediate images share both shape and color information from the original images and can be measured as being a certain physical distance from either starting image. Similar morphing procedures have been used by previous emotion researchers (for example see Young et al., 1997).

In four empirical chapters this thesis closely investigates several aspects of categorical perception of emotional facial expressions that have thus far been overlooked in the literature. Chapter 2 is an investigation into the individual differences of categorical perception which highlights the fact that not every person perceives emotional facial expressions in categorical manner. Chapter 3 investigates perception of surprised faces and suggests some reasons that although surprise is considered to be a "basic" emotion the categorical perception literature has had conflicting findings. Chapter 4 investigates development and posits that categorical perception is adaptive and may be found in young children because it will help them navigate the social environment. Finally, Chapter 5 proposes a new methodology for studying some of these previously investigated questions that relies on eye direction rather than verbal response and could be used to compare performance across diverse groups.

CHAPTER 2

INVESTIGATING THE CATEGORY BOUNDARIES OF EMOTIONAL FACIAL EXPRESSIONS: EFFECTS OF INDIVIDUAL PARTICIPANT, MODEL AND THE STABILITY OVER TIME

2.1 Preamble

Past research has shown that emotional facial expressions are perceived categorically (Etcoff & Magee, 1992). Broadly speaking this means that individuals perceive emotional expressions in categories, glossing over minor differences in expression. Specifically, people are more accurate when they discriminate two images that are from different categories of expression (i.e., happy and sad) than when the two images are drawn from within the same category, even if those expression images are the same physical difference apart (Repp, 1984).

Several researchers have investigated categorical perception of emotional facial expressions (for example, Calder, Young, Perrett, Etcoff, & Rowland, 1996; Etcoff & Magee, 1992; Sukuzi, Shubui, & Shigemasu, 2007) and reported performance based on group statistics. In none of the studies on categorical perception of emotional facial expressions are the data examined on an individual participant basis. Data based on means and group statistics can be problematic in that it may create or mask categorical perception. If individuals perceive stimuli categorically but their boundaries are different any increase in discrimination accuracy at these boundaries may be lost when scores are averaged. Conversely, an appearance of categorical perception might occur if the slopes of several individual identification curves differ. When averaged across individuals it is possible the deviant scores would alter the averaged curve in such a way that it appeared categorical even though the individual curves did not suggest this pattern. Several questions regarding categorical perception of emotional facial expressions remain. Are faces perceived categorically by all individuals? Does the identity of the individual expressing the emotion matter for perception of emotions? Is categorical perception stable (e.g., do individuals perceive the same stimuli differently at different times)? Are category boundaries the same across individuals?

Past research in other domains, such as categorical perception of speech sounds, has suggested that all individuals do *not* perceive auditory categories in exactly the same way. In a review chapter on the phonetic category boundary Repp and Liberman (1987) explore several situations or contexts that change the location of category boundaries for speech sounds or eliminate them entirely. A few of the areas they discuss are the context immediately preceding or following the speech sounds, the speaker's native language, the rate of speech production, the characteristics of the individual producing the speech (e.g., high or low pitched voice), and changes arising due to expectations of meaning derived from use of particular grammatical structure or word meaning. In addition, feedback on discrimination tasks has been shown to improve performance, using phonetic or auditory strategies can lead to different results for different individuals, and linguistic experience (for example, learning a new language) can change the way categorical perception tasks are done (Repp, 1984). All of these factors have been shown to influence categorical perception in the domain of speech sounds, but none has been investigated in the domain of emotional facial expressions.

In my exploratory study we show that individual differences occur in the perception of emotional facial expressions. The current study looks broadly at categorical perception of emotional facial expressions to determine if further research should be done on how category boundaries are identified and under what circumstances they will change. Little is known about individual differences in the position of the category boundary, nor the relative category boundaries for different stimulus continua. Similarly, little is known about whether an individual's category boundary is stable over time. I investigated these topics in a series of experiments, in which category boundaries were identified using converging evidence from identification and discrimination tasks. I compared across individuals as well as within individuals across two sessions that were separated by a week. Results show differences between individuals, and suggest that these differences are largely stable over time. I also found differences between continua of emotion displays developed from different models posing for emotion photographs.

2.2 Abstract

Past research has shown that facial expressions of emotion are perceived categorically. Little is known about individual differences in the position of the category boundary, nor the relative category boundaries for different stimulus continua. Similarly, little is known about whether an individual's category boundary is stable over time. We investigated these topics in a series of experiments, in which category boundaries were identified using converging evidence from identification and discrimination tasks. We compared across individuals as well as within individuals across two sessions that were separated by a week. Results show differences between individuals, and suggest that these differences are largely stable over time. We also found differences between continua of emotion displays developed from different models posing for the photographs.

2.3 Introduction

The consensus in the field of emotional face perception is that facial expressions are perceived categorically (Calder, Young, Perrett, Etcoff, & Rowland, 1996; de Gelder, Teunisse, & Benson, 1997; Etcoff & Magee, 1992; Young et al., 1997). However, little is known about individual differences in category boundaries, the stability of individual differences over time, and the effects of using different models to portray the facial expressions. The two experiments described here were designed to explore these topics.

Categorical Perception

The hallmark of categorical perception is dissociation between the physical dissimilarity of stimuli and the psychological distance between them. Psychological distance can be measured in a number of different ways, including the reaction time necessary to distinguish two stimuli, the accuracy with which they are discriminated, and the explicit similarity reported by the participant (Repp, 1984). The psychophysical responses given to stimuli in a number of domains suggest that at the perceptual level these stimuli are being grouped (Harnad, 1987). That is to say, perceived similarity is not predicted simply by physical similarity. A number of different domains for which categorical perception occurs have been identified, including speech sounds (Eimas, 1963; Liberman, Harris, Hoffman, & Griffith, 1957), colors (Bornstein & Korda, 1984), and vocal emotional expressions (Laukka, 2005).

Typically, categorical perception is investigated by studying the perception of a continuum of stimuli that are equally physically distant from one another and span a category boundary. Participants perform two tasks: an identification task and a discrimination task. The identification task can be a free naming task, in which stimuli are presented and participants give their own identification categories, or as is more typical, the stimuli can be presented in the format of a 2-alternative-forced-choice (2AFC) experimental paradigm. In the latter case participants are supplied with the two category labels that best describe the endpoints of the continuum, and are required to respond with one of the two labels. Even in a free response paradigm where participants are not restricted responding with one of two category labels, participants tend to classify stimuli as one of the two exemplar categories, even when the stimulus is intermediate (Etcoff & Magee, 1992).

The second task is a discrimination task. The discrimination task results in accuracy scores when participants discriminate the pairs of stimuli from the same continuum used in the identification task. A common way to test discrimination performance is through matching tasks. For example, the ABX matching task, requires participants to compare two sequentially presented images and determine which of the first two matches a third image, image X (Calder et al., 1996; Etcoff & Magee, 1992; Repp, 1984). Another way to assess discriminability is a matching task in which two of the stimuli are displayed and the participant makes a decision of "same" or "different" (Calder, et al., 1996).

Using the information from the identification and discrimination tasks together, categorical perception can be inferred if the following conditions are met (Harnad, 1987; Repp, 1984; Studdert-Kennedy, Liberman, Harris, & Cooper, 1970): From the identification data response curves are graphed such that the points along the continuum are represented on the x axis and percent response on the y - axis. If the continuum is perceived categorically, it is expected that the curve will be “s-shaped”, such that the slope changes from one category distinction to another. The point of maximal slope is the 50% identification point (Repp, 1984; Studdert-Kennedy et al., 1970), the point at which stimuli are maximally ambiguous. This point is likely to be the category boundary. The 50% identification point is then compared to the discrimination accuracy performance. If the peak in performance in the discrimination task occurs at the same point as the 50% point in the identification task, this is taken as strong evidence of categorical perception as well as evidence that the categorical boundary has been identified (Repp, 1984). This peak reflects the fact that it is easier to perceive stimulus differences when they cross a perceptual category compared to stimulus discriminations with the same physical distance that are within a category.

Some authors have also used reaction time to support their claims of categorical perception by looking at changes in reaction times across the continuum in the identification task (Bornstein & Korda, 1984; de Gelder, Teunisse, & Benson, 1997). Participants are fastest at identifying stimuli when they are furthest away from the category boundary and closer to a prototypical instance of the category. In addition, participants are fastest at discriminating two stimuli when they cross a category boundary than when the discrimination is within category. This reaction time finding mirrors that of accuracy performance.

Categorical Perception and Emotional Facial Expressions

Etcoff and Magee (1992) used converging evidence from an identification task and a discrimination task, as described above, in the first demonstration that emotional facial expressions are perceived categorically. Participants performed an identification task and a discrimination task using line drawings of a continuum of physically equidistant facial expressions. Discrimination was more accurate between facial expressions when the two images fell on either side of the category boundary than when the two drawings were from within the same category – even when these drawings were physically different by the same amount. The authors suggest that there is a functional aspect to this particular perceptual categorization. If individuals are specialized for detecting the emotional states of others, this mechanism may allow us to efficiently determine others' emotional state and therefore plan our own behavioural response accordingly.

Subsequently, other studies have investigated categorical perception in emotional facial expressions. Calder et al. (1996) improved upon these methods by using morphed photographs rather than line drawings to investigate this phenomenon. Using these more naturalistic stimuli, Calder et al. were able to replicate the findings of Etcoff and Magee (1992) and agreed that emotional facial expressions are perceived categorically. In addition, they ruled out effects of working memory on the task by decreasing the amount of information that needed to be held in memory to complete the task. To reduce memory demands, the authors implemented a "same" or "different" approach to the discrimination task. In this task two images were presented simultaneously and the participants' task was to determine whether the two images matched. The results obtained from this task mirrored those of the original discrimination task. Those images within a category were more difficult to discriminate than those that straddled a category boundary, even when the physical distance between these images was equal.

Other authors have since investigated categorical perception of emotional facial expressions using photographs but have extended the findings to all pairings of the six basic emotions (happy, sad, anger, disgust, fear, surprise) (Young et al., 1997) and have investigated how inversion affects categorical perception (de Gelder et al., 1997). De Gelder et al. (1997) determined that categorical perception was reduced by inversion, concluding that the relevant information of categorical perception may be configural in nature, as it is known that inversion disrupts configural processing (Valentine, 1988).

This previous research has investigated categorical perception of emotional facial expressions broadly, but has not closely examined some key questions, such as the location of the category boundary. Little attention has been placed on the influence of the particular stimuli used in categorical perception experiments involving emotional facial expressions. This contrasts sharply with the research done on speech sounds where different types of sounds have been tested and compared and form an important basis for some theories of categorical perception in this domain (Fry, Abramson, Eimas, & Liberman, 1962; Liberman et al., 1957; Liberman, Harris, Eimas, Lisker, & Bastian, 1961). Finally, individual differences in task performance have been overlooked. When group data are presented atypical responses are masked which may limit our understanding of an individual's categorical perception.

Present Research

The current research aims to further investigate the category boundary with respect to several remaining questions regarding emotional facial expressions. Data based on means and group statistics can be problematic in that it may create or mask categorical perception. If individuals who perceive stimuli categorically have different boundaries any increase in discrimination accuracy at these boundaries will be lost when scores are averaged. Conversely, data may suggest categorical perception if the slopes of several individual identification curves differ. When averaged across individuals it is possible the diverse scores would alter the averaged curve in such a way that it appeared categorical even though the individual curves do not suggest this pattern. Our study aims to resolve some of these issues. In our first experiment we compared the category boundaries for all individuals portraying the emotional expression tested. We also examined individual differences in performance on categorical perception tasks to determine if the reported overall results match the behavior of individual participants. In our second experiment we included a discrimination task to determine whether all individuals met the criteria for categorical perception. In addition, we added a second session which allowed us to look at performance over time.

2.4 Experiment 1

The goal of the first experiment was to investigate the location of the category boundary for four happy-sad continua of emotional images. The experiment was designed to determine the specific location of the category boundary and to compare these locations across individual participants and across models.

Method

Participants

Thirty undergraduate students (*mean age* = 20.03, *SD* = 2.69, 6 males) from the McMaster University psychology participant pool received partial course credit for participation in this experiment. All participants had normal or corrected-to-normal vision.

Stimuli

Stimuli in this experiment consisted of morphed continua of emotional facial expressions. The endpoints of these continua were photographs from Ekman and Friesen's (1976) *Pictures of Facial Affect*. Four individuals from the complete set were used (C, EM, GS, NR) and continua were created from their images. The endpoints of the continua were the original happy image and the original sad image. Happy and sad were chosen as endpoint images because they are unambiguous and not as easily confused as some other basic emotions (Palermo & Coltheart, 2004). The percentage of individuals judging the happy and sad face stimuli to be the expression reported by Ekman and Friesen (1976) are different for the two expressions. Palermo and Coltheart found happy expressions to have higher percent agreement (*mean* = 100%) than sad expressions (*mean* = 59.4%). Intensity between the two expressions also differed. The 4 happy expressions were more intense (*mean* = 5.6, on a 7-point scale) than sad expressions (*mean* = 3.8). Despite these differences in agreement and intensity, these two emotional expressions have been consistently found to be perceived categorically and therefore seemed an appropriate choice for investigating any possible individual differences (Calder, Young, Perrett, Etcoff, & Rowland, 1996; Etcoff & Magee, 1992).

Morphed continua were created using Morpheus v1.85 software. The software requires the user to supply matching locations on two images and an average is computed and intermediate images created. This program uses vector averaging to create morphs such that both shape and color information are preserved from the original images. On average 182 points were identified on each face, the exact number dependent upon the salient features unique to each face image. Each resulting continuum included 9 intermediate images and 2 endpoint (original) photographs for a total of 10 steps in each continuum. The original images were presented in black and white but altered using Adobe Photoshop 7.0 to remove identifying tags and to make all images a consistent brightness (*average luminance* = 64.6 cd/m^2). The 4 continua used in the following experiments can be seen in Figure 1.

Test stimuli were the five middle (the most ambiguous) images. The six extreme (unambiguous) images were used during training. Previous research (e.g., Etcoff & Magee, 1992) suggests that these endpoint images are consistently categorized as an emotion label and are unlikely to be part of a category boundary.

(Figure 1 about here)

Procedure

Participants were seated and positioned in a chin rest such that their eyes were 57 cm from the display. Participants were instructed to determine the emotion displayed on the face and were given the 2 alternative forced choice in which they could choose "happy" or "sad". Participants made their response via keyboard.

Both training and test trials were structured as follows: Participants were presented with a fixation cross in the center of a white screen for 500 ms. This was followed by the image that they were asked to categorize. The morphed image was presented until the participants made a response up to a maximum of 5000 ms. If any trial reached the 5000ms threshold, the trial timed out and no response was recorded for that trial. Stimuli were presented on an 18 inch (45.72

cm) NEC MultiSync FE990 flat CRT monitor controlled by a PC computer running Windows XP Professional with an Intel Pentium 4 processor. The experiment was run using E-Prime software version 1.0. Images presented on the screen were 9.75 by 14.5 cm, and as the participants were seated 57 cm away such that the visual angle subtended by the images was 9.75° by 14.5°.

A training block preceded the test blocks. The training served to ensure participants understood the task instructions and provide them with an opportunity to become familiar with the task. During training, participants were asked to categorize the 6 images from the ends of the continua (3 from each end) as "happy" or "sad". Once participants reached a criterion of 6 consecutively correct responses they moved on to the testing part of the experiment. Participants were given feedback on their performance. On training trials, feedback was presented visually with "correct" or "incorrect" being displayed for 1500 ms after the response. It took participants an average of 6.41 (*SD*= 1.09) trials to move on to the testing part of the experiment. All but 5 of the 30 participants were able to complete the training in the first 6 trials.

On test trials, the next trial was immediately presented after the previous trial was completed. On each test trial participants saw one of 20 unique images of morphed happy-sad continua 40 times in random order (800 test trials total). Response (happy, sad) and reaction time were recorded. Each session lasted approximately 40 minutes.

Results and Discussion: Experiment 1

To determine the category boundary for the happy-sad continuum results were analyzed in two ways: by model and by individual.

By Model

The data were split by model (the individual in the photographs portraying the expression) and graphed as percent response happy (see Figure 2). For 3 of the models (C, GS, NR) the curves cross the 50% identification point at the middle photograph in the continuum, which was image 6. For one model (EM) the 50% identification point was at image 7, shifted one image to the right. At the individual level the category boundaries ranged from image 5 to 7 for all 4 models. For C, GS, and NR the boundary was most often located at image 6, in the middle of the continuum. For EM the category boundary was most often located at image 7.

(Figure 2 about here)

Reaction time data mirrored these results (Figure 3). For models C, GS, and NR, there was a peak in reaction time at the 50% identification point, suggesting that this middle image was more difficult to categorize. Similarly for model EM, whose 50% identification point was shifted on the continuum to image 7, the reaction time peak also occurred at image 7. Taken together these results suggest that the model influences the category boundary. Model EM's images are seen as more "sad" for more images along the continuum than are the other models that we tested. One possibility for this is that the original images used to create the continua differed in intensity of expression. Palermo and Coltheart (2004) reported intensity ratings for all models we tested; however EM's original photographs were not rated as either more intensely happy or sad compared to the other 3 models tested. Percent agreement on EM's sad expression was low (41.7%), however this was the same percent agreement as GS's sad expressions in Palermo & Coltheart's study. EM's happy expression was rated as highly as any other individual's expression (100%) therefore it is unlikely this is the cause of these results.

(Figure 3 about here)

By Individual

Next we tested for individual differences across participants. Identification curve and reaction time data were analyzed by looking at the graphs from each model (4) for every participant (30). While the majority of the cases (76.67%) followed the expected "s-shaped" pattern of identification results, some participants had patterns of results that did not show the expected pattern. These patterns fell into 3 main groups: 50% identification point and reaction time peak mismatch (17.50%), clear 50% identification point but no reaction time peak (4.17%), and no 50% identification point (response of mostly happy or sad to all test images) (1.67%). For the instance of 50% identification point and reaction time peak mismatch all participants were mismatched by only a single step on the continuum. For example, the 50% identification point occurred at image 5 and the reaction time peak occurred at image 6, as shown in Figure 4a. In some instances, a clear reaction time peak could not be discerned, making it impossible to compare with the identification point (Figure 4b). In two instances (1.67% of cases) the individual categorized most images from the middle of the continuum as either happy or sad. This resulted in no 50% identification point for that participant as can be seen in Figure 4c. All together, these performance differences (accounting for 23.33% of the total) suggest that not all individuals have clear category boundaries, or in the case of the individuals with no 50% identification point, their category boundary lies outside the span of images we tested. We used a large number of trials per participant so this finding likely doesn't reflect measurement error. Instead, certain individuals seem to perform this task in a way that was unexpected. These results may have been obscured by previous authors reporting only group statistics. We also investigated the possibility that the performance differences were being driven by a few individuals or a particular model. This appeared not to be the case, performance differences occurred for each of the models tested and a variety of individuals showed these differences. When a clear category boundary was not found most often that individual had a clear boundary for the other 3 models we tested. We wanted to determine if atypical responses were due to a subset of the population not perceiving these faces categorically. To this end we added a discrimination task to assess categorical perception and a second session to determine the reliability of performance over time.

2.5 Experiment 2

Experiment 2 was designed to further explore differences in individual performance found in experiment 1. Participants were invited for two sessions, separated by a one week interval, to test whether individual category boundaries were stable over time. In addition, a discrimination task was added to ensure that the continua were indeed perceived categorically.

Method

Participants

Thirty naive undergraduate students (*mean age* = 18.00, *SD* = 0.79, 5 male) from the McMaster University psychology participant pool received partial course credit for participation in this experiment. All participants had normal or corrected-to-normal vision. Six additional participants did not complete the second session of the experiment and were excluded from the experiment.

Stimuli

The stimuli were identical to those described for experiment one.

Procedure

The second experiment differed from the first in that participants were asked to complete two experimental tasks, an identification task and a discrimination task, and to complete two sessions. Experimental setup was the same as described for experiment one.

The identification task was identical to that described in experiment one except it included fewer trials so that the total session could be completed in an hour. In the test trials participants saw a total of 20 unique face morph images (5 for each model) 10 times each for a total of 200 identification trials per session. Participants were trained on this task immediately before the test trials and were required to correctly categorize 6 consecutive images as happy or sad by pressing the appropriate key on the keyboard.

A discrimination task was added to the experiment to ensure that the continua were indeed perceived categorically for these stimuli. The discrimination task took the form of an ABX matching task. In this task the participant saw a series of images and made a matching decision about the images presented. A trial began with a fixation (250ms), blank screen (250ms), image A (750ms), blank screen (250ms), image B (750ms), blank screen (500ms), image X (1000ms), and a final blank screen that remained until the participant responded. The participant's task was to evaluate images A and B and to determine which of the two matches the last image (X) that was presented. Participants indicated their response after the last image was presented via the keyboard. Response and reaction time were recorded. Training preceded the task and participants were required to correctly match the 6 unambiguous images (3 from each end of the continuum) in an ABX paradigm 6 consecutive times. For example, unambiguous "happy" images had to be discriminated from unambiguous "sad" images. To reduce the likelihood that participants would use emotion labels during the matching task the discrimination task always preceded the identification task.

The second session was exactly the same as the first and always took place 7 days following and at the same time of day as the first session. All participants repeated the training trials on the second session to ensure they remembered the task instructions.

Results and Discussion: Experiment 2

Results were analyzed within each session to determine the match between fifty percent identification point and peak in accuracy performance and then compared between sessions to test for stability of category boundaries over time.

Identification/Discrimination Match: Categorical perception

Performance was examined at the individual level (every participant for all 4 models) for a match of 50% identification point and peak accuracy on the discrimination task. The image that was closest to the point where the slope crossed 50% was classified as the 50% identification point. If more than one image was classified as happy 50% of the time then both images were coded as that individual's 50% identification point (4.17 % of cases). The discrimination accuracy peak for each participant was the image pair with the most accurate discrimination. In the event that an individual was equally good at discriminating more than one image pair, both pairs were recorded as the peak (7.5% of cases). If identification performance predicted discrimination performance, we concluded that the facial expressions were perceived categorically. In the event an individual had more than one 50% identification point or discrimination accuracy peak, they were required to match both images to be counted as matching 50% identification point and discrimination accuracy peak.

Table 1 shows the match between identification and discrimination performance broken down by model for each participant. In the first session 65.83% of cases matched performance on the two tasks. In the second session, 73.33% of cases matched performance on the two tasks. These data indicate that for most individuals, performance is categorical. Of those instances (73 of 240) where performance did not match on the two tasks, 87.67% were off by 1 image. The remaining mismatches were made up of mismatches of greater than 1 image difference or performance differences similar to those seen in the unusual patterns of experiment 1 (such as no 50% identification point).

(Table 1 about here)

Performance Stability: Session one vs. session two

Figure 5a,b shows overall performance on the identification and discrimination tasks for each session (one and two). The discrimination performance, Figure 5a, highlights two trends occurring over the sessions. In session one there is a significant ($\chi^2 = (3, N = 30) = 8.79, p < .05$) dependence of the categorical pattern of accuracy on image pair. This is not the case for session two ($\chi^2 = (3, N = 30) = 3.82, p > .05$) where categorical patterns for accuracy performance did not depend on image pair. Figure 5b shows results from the identification task. Chi-squared analyses revealed that in both session one (χ^2 = (4, N = 30) = 7735.79, $p < .05$) and session two (χ^2 = (4, N = 30) = 6983.27, $p < .05$) response for this task depends on image. It is unclear why participants fail to show a significant peak in accuracy for the discrimination task in session 2. With more practice with the task, we predicted that accuracy would remain the same or increase during the second session, and using a paired t-test we confirmed that individuals were more accurate in the second session than in the first, $t(29) = -2.33$, $p < .05$. It does not explain the absence of a peak in performance; however peaks may be masked because of individual differences in the location of the peak.

(Figure 5 about here)

Table 2 shows the match between session 1 and session 2 performance for individuals. For the identification task, 92.50% of cases matched performance over the two sessions, suggesting that when perception was categorical, the boundary remained in the same place for most individuals. For the discrimination task, 76.67% of discrimination accuracy peaks were the same over the two sessions. This suggests that for most individuals, the categorical nature of perception is stable over time. In addition, non-matching performance was assessed. Of those instances (37 of 240) where there was mismatched boundary (from the identification data) and peak accuracy (determined by the discrimination data), over the two sessions 56.76% were a single image step away. This again suggests that performance is stable – even though individuals do not reach the criteria to infer categorical perception they still perform similarly to those who do.

(Table 2 about here)

Performance stability was also assessed by examining the individuals who did not perform with the median response. In this case we defined median response to refer to participant who had an "s-shaped" identification curve and whose discrimination performance was predicted by their 50% identification point. Figure 6a and 6b exclude individuals who had the median response in the first session and show the remaining individuals who responded alternatively. Overall, 94.74% were consistent, they had the same identification point or accuracy peak in sessions one and two, and 5.26% were inconsistent. These data specifically suggest stability of perception because it is not only those individuals who are performing at the median who have stable performance, but those individuals who perform outside the typical range as well. Again we were interested in whether performance differences were being driven by a few individuals or a particular model. Performance differences occurred for each of the models tested and a variety of individuals showed these differences. If performance was not categorical for an individual looking at a particular model it usually was for the other 3 models we tested. Non-median responses occurred for some individuals for some models, but not necessarily for particular individuals or particular models.

(Figure 6 about here)

2.6 Overall Discussion

These experiments are a first step in examining individual differences in categorical perception of emotional facial expressions. For most individuals these data suggest categorical perception of emotional facial expressions for the individuals tested. In the small number of cases in which we did not find evidence of categorical perception results do not exclude this possibility, since the difference in 50% identification point and discrimination accuracy peak were small for these few individuals. All previous studies on categorical perception of emotional facial expressions have reported only group level results. These experiments go beyond what previous researchers have reported by analyzing the individual results in category boundaries.

This is also the first time that performance stability has been tested. We tested individuals with the same identification and discrimination tasks over two sessions, separated by one week. We found that the majority of participants performed consistently, that is, their identification performance and discrimination performance remained stable across the two weeks whether they perceived the stimuli categorically or not. Categorical perception appears to be robust for the individual. Even with increased exposure to the manipulated stimuli, participants continue to perform categorically for the tasks.

One criticism that has been levied against proponents of categorical perception is that the use of accuracy data from an ABX discrimination task can result in a biased measure of sensitivity (Macmillan, Kaplan, & Creelman, 1977). In addition, identification slopes may be skewed by averaging data across individuals with varying category boundaries. By analyzing our data in this manner, we have shown that categorical perception occurs at an individual level for most individuals tested; suggesting previously published group statistics are not biased.

While we know that categorical perception is present, it is important to note that the specific category boundary is not the same for all individuals. Category boundary also depends on the model posing the expression; most individuals have the same category boundary for a particular model. For those individuals not showing evidence of categorical perception the strategy they are using to complete the tasks is unknown. We do know that their results are similar to those who show evidence of categorical perception, their identification and discrimination performance for the most part are only a step away on the continuum, and there are a small number of these cases. There are many possible reasons for these differences and future studies are needed to determine if any preexisting characteristics of the participants influences performance. One possibility is that categorical perception is influenced by mood. For example, Joorman & Gotlib (2006) found that individuals diagnosed with major depression required more intense emotional images to label an expression. We also know their perception tends to be stable over time, ruling out sampling error as a potential reason for these differences in individuals' performance.

We also examined the influence of the individual modeling the emotion on categorical perception. We found that category boundaries can differ between models. Of those tested, one model consistently differed with respect to the location where most individuals switched categorizing from happy to sad. Any attempt to compare results across studies and even within a study should take this into consideration. Discrepant or unexpected results may be influenced by the choice of stimuli, particularly in this type of experiment. The reason for differences in category boundary between models is unclear. It is possible that differences in intensity at the endpoints influence the category boundary – more intense expressions on one or both ends of the continuum could change how the continuum appears and how it is perceived. This appears not to be the case with the stimuli we used. Palermo and Coltheart's (2004) ratings of intensity were similar for the endpoint images between the models we used. It should be noted, however, that happy expressions are recognized significantly more accurately than sad expressions (Palermo & Coltheart, 2004) and it is unknown how this bias influences participants in a task using morphed expressions, such as ours.

One unexpected finding was that in the second session, there was no peak in accuracy on the discrimination task when all of the participants' data were considered together. This was puzzling because individually, participants were more accurate in the second session and were still performing the tasks categorically, that is, their identification and discrimination task performance matched across sessions. One difference between the two sessions was that individuals had prior exposure to the identification task (and therefore the strategy of naming the emotions) by the second session and they may have therefore used a different strategy when they were performing the discrimination task. Performance may have been enhanced by this strategy making all picture pairs equally difficult to discriminate thus eliminating any accuracy peak that was present. In one study verbal interference was found to disrupt categorical perception: repetition of adjectives describing the facial expressions being tested removed the advantage participants showed when discriminating between category pairs compared to within category pairs (Roberson & Davidoff, 2000). We also cannot assume that participants were fatigued during the experiment and therefore performing worse for in the second session. Accuracy was higher in the second session.

One methodological issue that arose from attempting to locate the category boundary using only a subset of the full continua was that for one model (EM), whose category boundary appeared to be shifted, it was difficult to determine the shape of the identification curve due to the limiting boundary we imposed on the number of stimuli tested. Having not tested the full range of stimuli we infer that identification would continue to decrease for the rest of the continuum. Despite that limitation, we were still able to identify the category boundary and we matched the discrimination peak to that boundary in experiment 2. Other studies (e.g., Calder, et al., 1996) have used this particular model and found performance to be categorical. Future studies could systematically vary features of faces (for example, open or closed mouth smiles) to determine if there are changes in boundary due to these differences in starting stimulus. This however was beyond the scope of the current investigation.

Our two experiments demonstrate that categorical perception of emotional facial expressions is a robust phenomenon with a few consistent performance differences. These differences are worth considering especially when using categorical perception tasks with groups other than typical adults where data may be even more variable. These findings highlight some of the important caveats that categorical perception researchers face, not only in the area of emotional facial expressions, but across domains as well.

2.7 References

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2.8 Tables & Figures

Table 1

Correspondence of ID and ABX Tasks

	Raw Score (/30)		Percent Correspondence	
Model	Session 1	Session 2	Session 1	Session 2
NR	24	20	80.00	66.67
GS	20	25	66.67	83.33
EM	17	18	56.67	60.00
C	18	25	60.00	83.33
Average Overall	**19.75**	**22.00**	**65.83**	**73.33**

Table 2

Consistency of 50% Identification Point on Identification task and Peak in Accuracy for ABX task

	Raw Score (/30)		Percent Correspondence	
Model	50% Identification Match	Discrimination Performance Peak	50% Identification Match	Discrimination Performance Peak
NR	26	24	86.67	80.00
GS	29	23	96.67	76.67
EM	28	22	93.33	73.33
C	28	23	93.33	76.67
Average Overall	**27.75**	**23.00**	**92.50**	**76.67**

Table 2 shows the consistency of the category boundary and the discrimination accuracy peak over 2 sessions broken down by model. The raw score shows the number of participants whose 50% identification point matched on both sessions and the number of participants who had a discrimination performance peak at the same location on the continuum for both sessions.

Figure Captions

Figure 1. Morphed continua used in experiments 1 and 2.

Figure 2. Identification curve for responses in experiment 1 shown by model.

Figure 3. Reaction time responses to each image in experiment 1 shown by model.

Figure 4. Examples of the 3 unpredicted responses in experiment 1. a) 50% identification point and reaction time peak mismatch. b) No reaction time peak. c) No 50% identification point.

Figure 5. Overall identification and accuracy for experiment 2 by session. a) Accuracy on ABX task. b) Identification curve.

Figure 6. Identification (a) and discrimination (b) task consistency over sessions for individuals who were not performing at the median response.

Figure 1

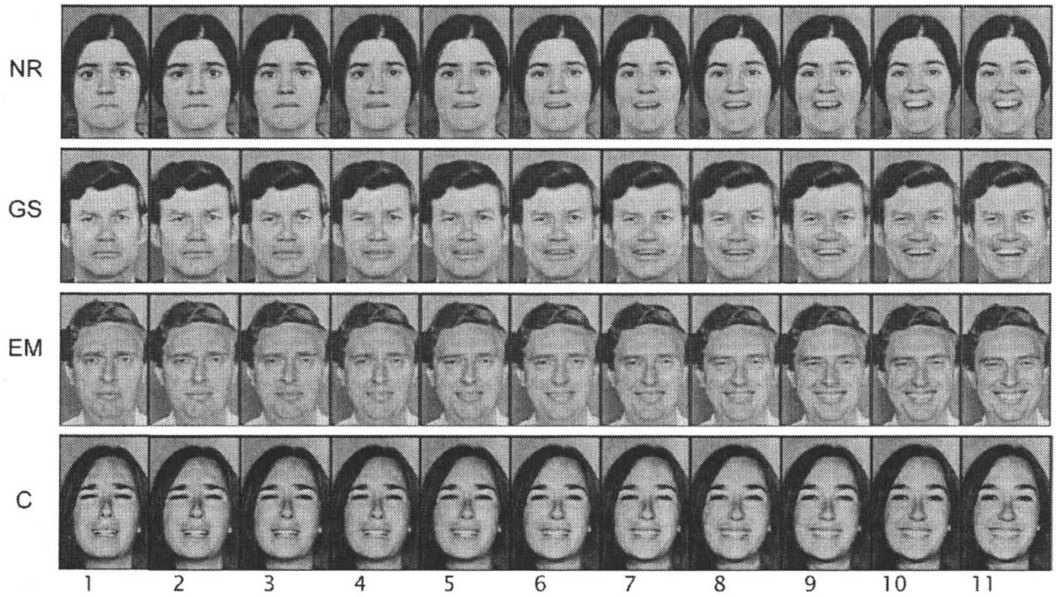


Figure 2

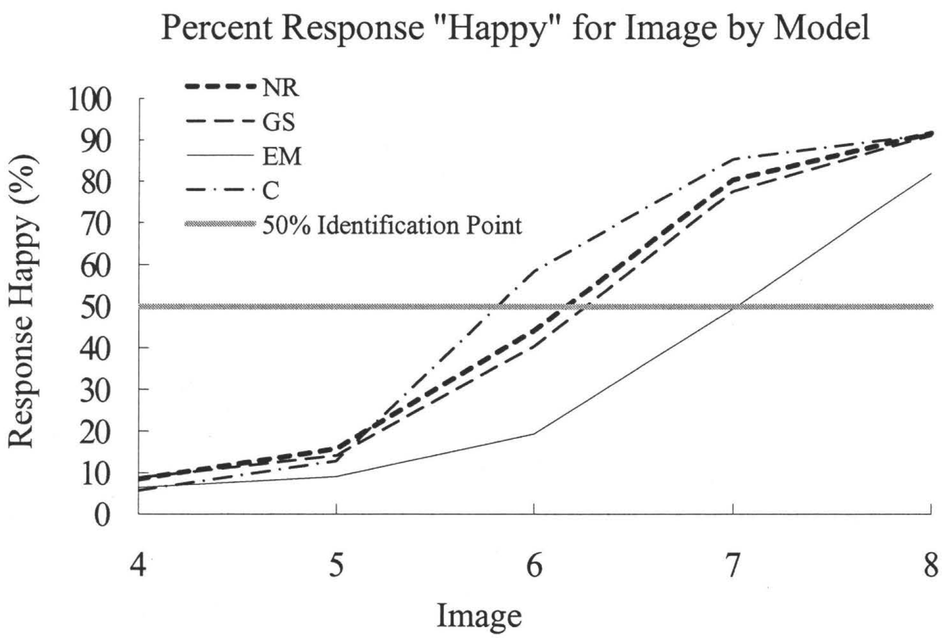

Percent Response "Happy" for Image by Model
NR
GS
EM
C
50% Identification Point
Response Happy (%)
100
90
80
70
60
50
40
30
20
10
0
4
5
6
7
8
Image

Figure 3

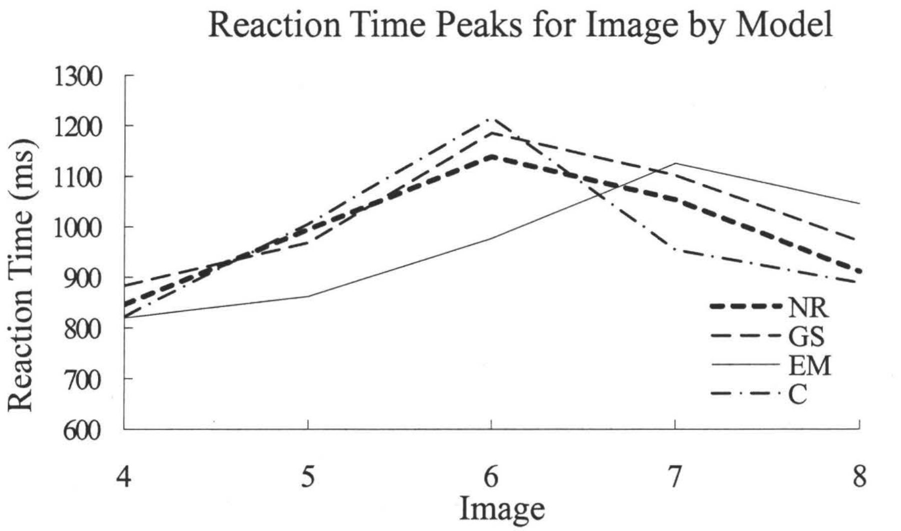

Reaction Time Peaks for Image by Model
Reaction Time (ms)
1300
1200
1100
1000
900
800
700
600
4
5
6
7
8
Image
NR
GS
EM
C

Figure 4

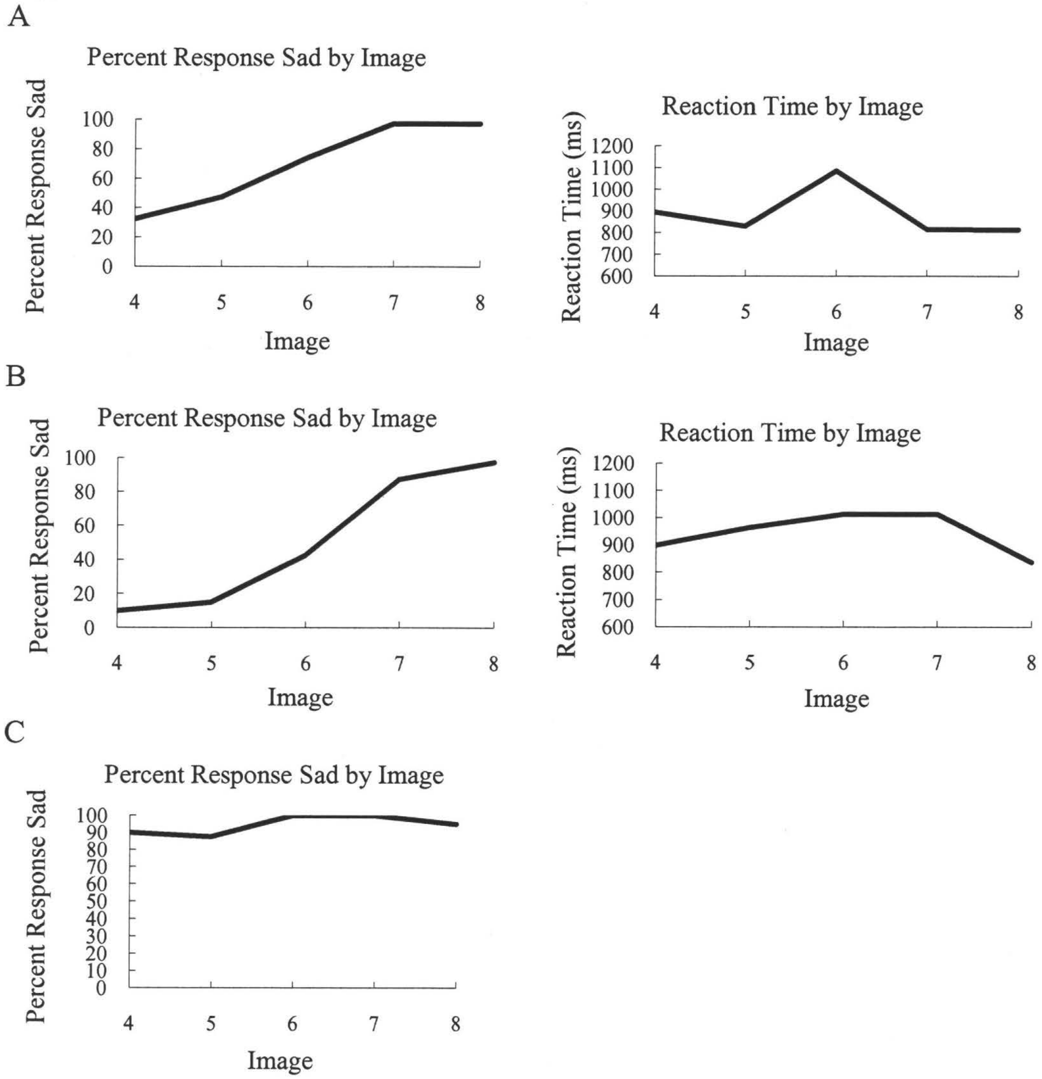

A
Percent Response Sad by Image
Percent Response Sad
100
80
60
40
20
0
4 5 6 7 8
Image
Reaction Time by Image
Reaction Time (ms)
1200
1100
1000
900
800
700
600
4 5 6 7 8
Image
B
Percent Response Sad by Image
Percent Response Sad
100
80
60
40
20
0
4 5 6 7 8
Image
Reaction Time by Image
Reaction Time (ms)
1200
1100
1000
900
800
700
600
4 5 6 7 8
Image
C
Percent Response Sad by Image
Percent Response Sad
100
90
80
70
60
50
40
30
20
10
0
4 5 6 7 8
Image

Figure 5a

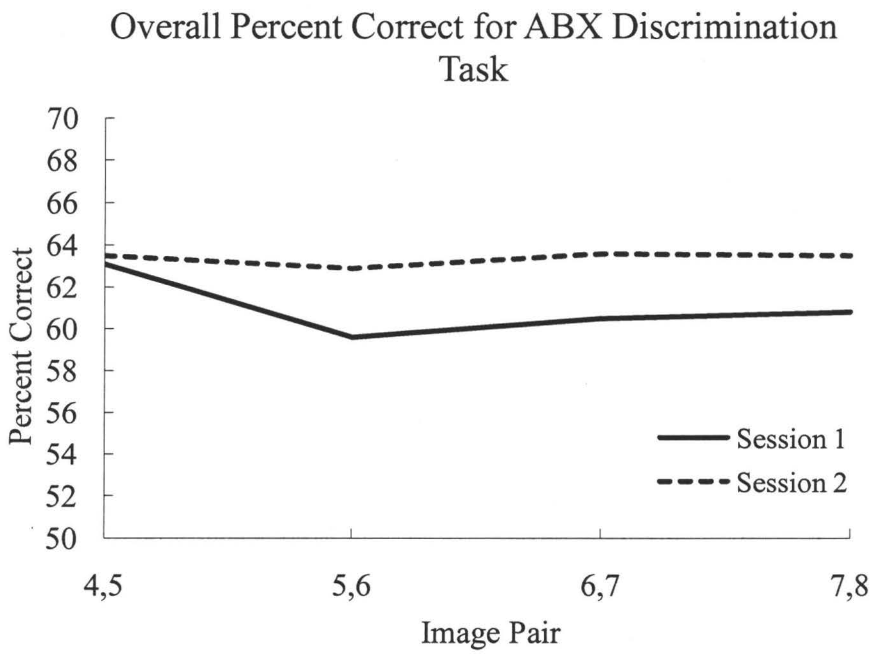


Figure 5b

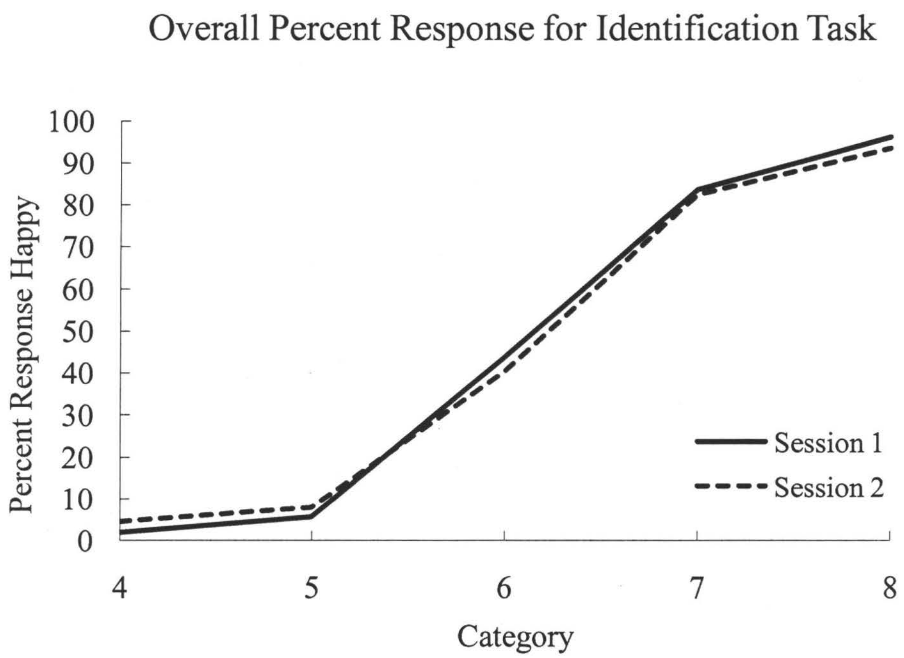


Figure 6a

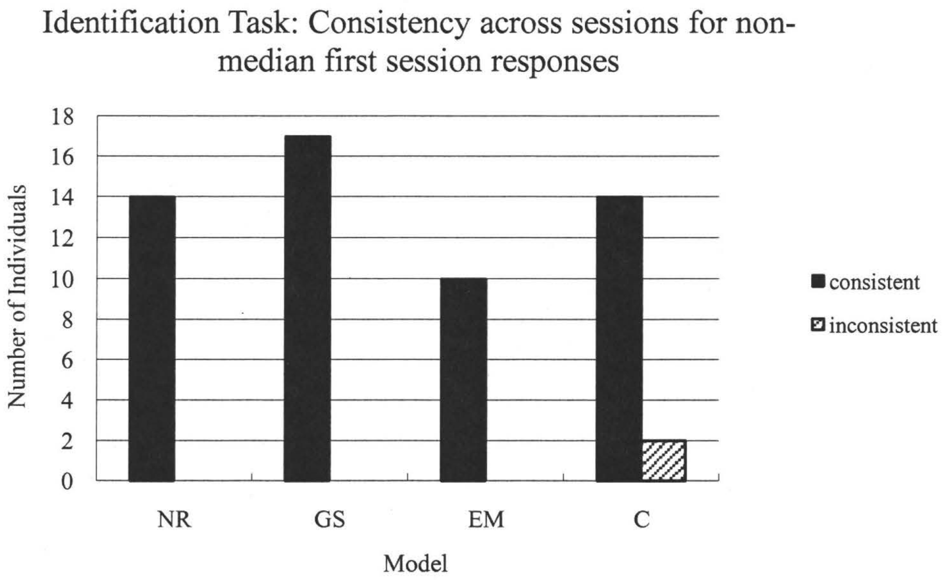
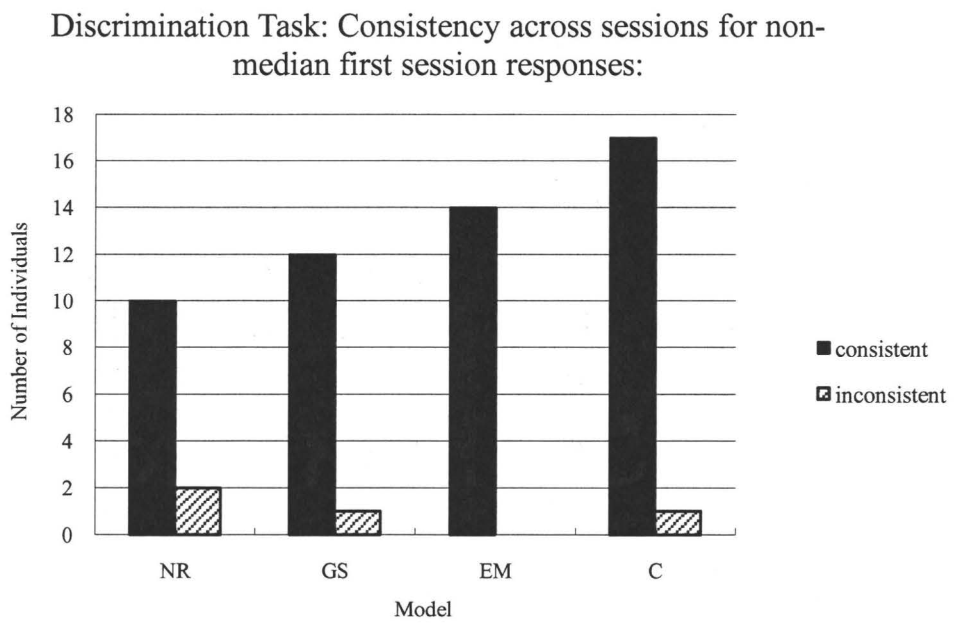


Figure 6b



CHAPTER 3

CONTEXT DEPENDENT CATEGORICAL PERCEPTION OF SURPRISE

3.1 Preamble

Categorical perception has been demonstrated for several types of stimuli, including speech sounds (e.g., Eimas, Miller, & Jusczyk, 1987), color (e.g., Bornstein & Korda, 1984), vocal emotional expressions (e.g., Laukka, 2005), and for visual displays of emotional expressions (e.g., Etcoff & Magee, 1992). In the laboratory categorical perception is tested with two tasks, identification and discrimination. Specifically, individuals are more accurate when they discriminate stimuli that are from different categories (i.e., images drawn from a morphed continuum spanning happy to sad) than when the stimuli are drawn from the same continuum but are within category (Repp, 1984).

While the study of categorical perception goes back to the early 1950's, the study of the phenomenon in emotional facial expressions is more recent, beginning with Etcoff and Magee's (1992) first investigation using line drawings of emotional expression morphed from one expression to another. Since that initial study categorical perception of emotional facial expressions has undergone further study. It has been replicated and extended by looking at all of the basic emotion pairings and using pictures instead of line drawings of faces (Young, Rowland, Calder, Etcoff, Seth, & Perrett, 1997). It seems that the finding of categorical perception in basic emotional facial expressions is robust.

When testing discrimination performance one emotional expression has not had the same robustness of results in the categorical perception literature. Evidence has been equivocal where surprise has been concerned. In Etcoff and Magee's original experiment on categorical perception of emotional facial expressions they found that all basic emotions were perceived categorically with the exception of surprised faces. They tested both happy-surprise and surprise-fear continua and found no evidence of categorical perception. That is, discrimination performance could not be predicted by identification performance as was the case with all other continua they tested. Etcoff and Magee suggest that surprise is, "combin[ed] with another emotion in perception rather than defining a category mutually exclusive with it". This interpretation is consistent with a functional approach to understanding perception of basic emotions in which categorical perception would be useful when it allows access to quick and accurate decision making. Because the motivation for a surprised face is ambiguous so too is the reaction required when confronted with a surprised face.

In contrast to Etcoff and Magee (1992) who found that surprise was not perceived categorically, Young, et al. (1997) tested all pairings of basic emotions and found evidence that surprise was perceived categorically. In their first experiment they tested identification of continua spanning happy-surprise, surprise-fear, surprise-sad, anger-surprise, and surprise-disgust. They found that identification suggested that these pairings were perceived categorically with steep slopes indicating a sudden "switching" of identification from one category to another. In a later experiment they tested discrimination of a subset of these continua (happy-surprise and surprise-fear) using both sequential and simultaneous discrimination tasks. They confirmed that perception of these stimuli was categorical, discrimination was more accurate on either side of the category boundary (for between category pairs) than for other within category pairs. One departure of this study from other studies of categorical perception of emotional facial expressions was that their continua contained 7 images total and 5 morphs (typically a continuum includes 11 images total, with 9 morphs), so it is not directly comparable to other published data.

Two other studies have found evidence for categorical perception of emotional facial expressions (Calder, Young, Perrett, Etcoff, & Rowland, 1996; de Gelder, Teunisse, & Benson, 1997) however; neither tested any continua that included surprise. These studies confirmed categorical perception in the continua they tested however; they added no data on surprise. Other emotion perception experiments involving surprise have also had equivocal surprise results. Rutherford, Chattha, & Krysko (2008) tested emotion aftereffects and found a functional relationship among the basic emotions other than surprise. Positive emotions (happy) had a negative aftereffect while negative emotions (anger, fear, sadness, and disgust) had mostly positive aftereffects. Adaptation to surprise elicited a mix of responses rather than one dominant response, consistent with the idea that the surprised expression was not consistently perceived as positive or negative.

These equivocal findings led me to question what it was about surprise that would make it different than other basic emotions and perhaps lead to a difference in perception for that emotion. An expression of surprise is inherently ambiguous; it could be positive or negative. Further, the interpretation of a surprised face depends on the situating context in a way that other basic emotions do not. A surprised face could indicate a situation to be avoided or simply an unexpected situation. It can also indicate a pleasant unexpected situation (e.g., a surprise birthday party). If this ambiguity interferes with categorical perception, then introducing a disambiguating context might facilitate categorical perception.

In the following study participants identified or discriminated images that were drawn from 3 morphed continua: happy-fear, surprise-fear, happy-surprise. Half were provided with a context for the surprise expressions in the form of a short description of a surprising situation. Both groups had typical identification curves, but discrimination performance was better predicted by identification in the context condition for happy-fear and surprise-fear continua, suggesting categorical perception for those stimuli presented with a disambiguating context. Surprise perception and threat relevance are discussed.

3.2 Abstract

Evidence regarding the categorical perception of surprise facial expressions has been equivocal: Surprise has sometimes been found to be perceived categorically like other basic emotions, and sometimes not. An expression of surprise is inherently ambiguous; it could be positive or negative. If this ambiguity interferes with categorical perception, then introducing a disambiguating context might facilitate categorical perception. Participants identified or discriminated images that were drawn from morphed continua: happy-fear, surprise-fear, happy-surprise. Half were provided with a context for the surprise expressions (a short description of a surprising situation). Both groups had a typical identification curve, but discrimination performance was better predicted by identification in the context condition for happy-fear and surprise-fear continua, suggesting categorical perception for those stimuli presented with a disambiguating context. Threat may be a particularly important factor in altered perception of surprised faces because the cost of missing a threatening face is high.

3.3 Introduction

Categorical perception describes a type of perception that occurs for many types of stimuli in multiple modalities, including speech, color, emotional facial expressions, and vocal emotional expressions (Bornstein & Korda, 1984; Calder, Young, Perrett, Etcoff, & Rowland, 1996; Eimas, 1963; Etcoff & Magee, 1992; Laukka, 2005). Categorical perception describes a phenomenon where an individual shows less acute ability to discriminate paired items that are the same physical distance when the pair is within a category, but has higher accuracy discriminating a pair that is the same distance apart but spans a category boundary (Harnad, 1987a; Repp, 1984). This type of perception is functional; it allows us to make quick judgments about category membership and presumably, act more quickly as a result (Harnad, 1987b). In the environment of evolutionary adaptedness (EEA) making quick decisions about approach and avoidance of individuals would have been beneficial while slow decisions could lead to costly mistakes (Cosmides & Tooby, 2000; Nesse, 1990). When an individual displays a happy expression it is safe to assume they can be approached (Fredrickson, 1998) however an angry expression is a signal that an individual should be avoided (Nesse, 1990).

Categorical perception is typically tested using two different tasks and a correspondence between the two tasks is taken as evidence for categorical perception (Repp, 1984). The first task is an identification task which determines the location of the category boundary. First, a continuum from one category exemplar to another is created. For example, categorical perception of color might be tested by examining different wavelengths which appear in the visible spectrum as green to blue. Each step in the continuum is presented to participants and they are asked to identify each sample. Typically a 2-alternative-forced-choice task is used for the identification task. In this case participants are given the two category exemplars (in the color example, green and blue) and are presented with all steps in the continuum in a randomized order. They match one of the two exemplars to each of the steps. This procedure has been validated by ensuring that when participants are given the task in a free recall format (in which the category exemplars are not given) they perform similarly to when they are given a 2-alternative-forced-choice (Calder et al., 1996; Etcoff & Magee, 1992). This validation suggests that participants do not have other preferred labels that they would use to describe the stimuli if the task was not a forced choice.

If perception is categorical this task results in an "s-shaped" identification curve from one category exemplar to the other. This particular shape results because participants identify most points along the continuum as one category exemplar or the other most of the time, and there is a relatively steep slope at the point where individuals "switch" from identifying one category over the other (Repp, 1984). The point along the curve at which responses are maximally ambiguous, 50% identification one category and 50% the other, is termed the 50% identification point and is presumed to be the category boundary (Repp, 1984; Studdert-Kennedy, Liberman, Harris, & Cooper, 1970). If perception were not categorical it would be expected that the identification curve would be a straight line or have a low slope, because participants would be using only the physical information from the stimulus to make an identity judgment. If participants are not categorizing the stimuli responses will be equally likely to be either category and an "s-shaped" curve would not be found.

For a conclusive test of categorical perception a discrimination task must be done to confirm better accuracy at the 50% identification point. In the typical discrimination task accuracy is assessed through a series of comparisons of pairs of two equally spaced points along the continuum. The most common task, an ABX task, requires participants to match a stimulus, called X, to one of two presented stimuli, A and B (Repp, 1984). X always matches one of A or B and A and B are always the same physical distance from each other on the continuum. Discrimination accuracy is plotted and if perception is categorical for the stimuli, there will be a peak in accuracy for the pair that straddles the category boundary that was determined in the identification task. Discrimination can also be measured using a same/different comparison or a delayed matching task (Homer & Rutherford, 2008; Young, Rowland, Calder, Etcoff, Seth, & Perrett, 1996). If perception is categorical, accuracy will "peak" (there will be higher accuracy in discriminating) where the pair straddles the category boundary (Harnad, 1987a; Repp, 1984; Studdert-Kennedy, Liberman, Harris, Hoffman, & Griffith, 1957).

Macmillan, Kaplan, and Creelman (1977) have identified a potential problem with research on categorical perception. They show that identification and discrimination performance results can be biased when data are averaged. If the slopes from individuals in the identification task are different or if their category boundaries are in different locations the averaged data may create data that look categorical. In addition, individuals typically have higher discrimination accuracy than their identification data predicts. Current definitions of categorical perception take this into account by requiring discrimination to be higher at the category boundary rather than being at chance for within category discriminations (Repp, 1984).

Categorical Perception of Emotional Facial Expressions

Several authors have examined categorical perception of surprise along with other basic emotions. Etcoff and Magee (1992) used line drawings to investigate categorical perception in the basic emotions. They found that all tested expressions, except surprise, were perceived categorically. They tested both happy-surprise and surprise-fear continua and found no evidence of categorical perception. That is, discrimination performance could not be predicted by identification performance as was the case with all other continua they tested. They reasoned that if surprise was harder to identify, then it might also be difficult to discriminate. However, surprise was identified similarly to other basic emotions and even results in an identification curve that suggests surprise may be perceived categorically. More recently, Young et al. (1997) tested categorical perception using morphed images of emotional facial expressions and concluded that surprise was perceived categorically.

Discrimination performance was predicted by identification for all the emotions they tested, including surprise.

Other emotion perception experiments involving surprise have also had equivocal surprise results. Rutherford, Chattha, and Krysko (2008) tested emotion aftereffects and found a functional relationship among the basic emotions other than surprise. Positive emotions (happy) had a negative aftereffect while negative emotions (anger, fear, sadness, and disgust) had mostly positive aftereffects. Surprise resulted in a mix of responses (happy, sadness, disgust, and anger) rather than one dominant response, consistent with the idea that the surprise emotion was not consistently perceived as positive or negative.

Results from past research suggest that surprise is different from other basic emotions. Etcoff and Magee (1992) suggest that surprise is, "combin[ed] with another emotion in perception rather than defining a category mutually exclusive with it". It may be that perception of surprised faces is enhanced by the context of the surprised face, and typical laboratory experiments do not have this additional information. In addition, an expression of surprise is inherently ambiguous; it could be positive or negative. A surprised face could indicate a situation to be avoided or a pleasant unexpected situation (e.g., a surprise birthday party).

We reasoned that if a prior belief influences perception of surprise then perhaps providing participants with this belief (a context) for the expressions in the experimental task could change their perception of surprise. There is some evidence outside of the categorical perception literature suggesting that emotion perception is influenced by context. Carroll and Russell (1996) found that the emotion reported to be on a face was consistent with the situation of the individual rather than the actual emotion displayed (e.g., an expression of anger was judged as fear when the context of the face indicated fear). We hypothesized that providing individuals with a story describing the model in a surprising situation would change their perception for surprise when paired with happy or fear, making it categorical. We tested this hypothesis by giving participants both happy surprise and fear surprise stories paired with two different models. We tested categorical perception for all three continua that could be created for these pairings (happy-surprise, happy-fear, and surprise-fear) in a between subjects design comparing a context and a no context condition. We also examined the nature of categorical perception of surprise by comparing the exact same tasks (identification and discrimination) with and without a context.

3.4 Methods

Participants

Sixty undergraduate students (*mean age* = 19.06, *SD* = 0.93) from the McMaster University psychology participant pool received partial course credit for participation in this experiment. All participants reported normal or corrected-to-normal vision.

Stimuli

Stimuli in this experiment consisted of morphed continua of emotional facial expressions. The endpoints of these continua were photographs from Ekman and Friesen's (1976) *Pictures of Facial Affect*. Two individuals (one male, one female) from the complete set were used (PF, WF) and continua were created from their images. The endpoints of the continua were one happy image, one fearful image, or one surprised image.

Morphed continua were created using Morpheus v1.85 software. The software requires the user to supply matching locations on two images and then vector averaging between matching locations is used to compute intermediate images. On average 178 points were identified on each face, the exact number dependent upon the salient features unique to each face image. Each resulting continua included 9 intermediate images and 2 endpoint (original) photographs for a total of 11 images in each continuum. The original black and white Ekman and Friesen (1976) images were altered using Adobe Photoshop 7.0 to remove identifying tags and to make all images a consistent brightness (*average luminance* = 62.0 cd/m^2).

Procedure

Participants were seated and used a chin rest such that their eyes were 57 cm from the display. Stimuli were presented on a NEC MultiSync FE990 flat CRT 42.72 cm monitor controlled by a PC computer running Windows XP Professional with an Intel Pentium 4 processor. The experiment was run using E-Prime software version 1.0. Face images presented on the screen were 9.75 cm by 14.5 cm, subtending 9.75° x 14.5°. A training block preceded the test blocks. The training served to ensure participants understood the task instructions and provide them with an opportunity to become familiar with the task. During training for the identification task participants were asked to identify the original images from the ends of the continua as "happy", "fearful", or "surprised". Discrimination task training required participants to complete a delayed matching task using two different endpoint images (i.e., happy vs. fearful). Once participants reached a criterion of 6 consecutively correct responses they moved on to the testing part of the experiment. Participants were given feedback on their performance and it took them an average of $M = 11.47$, $SD = 8.23$ trials to move on to the testing part of the experiment in the identification task and $M = 7.47$, $SD = 2.67$ in the discrimination task.

Participants were randomly assigned to context or no context condition, but each participant completed discrimination and identification. Discrimination was always the first task so that individuals did not use emotion labels to complete the task because they had done so in the identification task. For a breakdown of the groups and counterbalancing see Table 1. A single model was seen during the entire discrimination or identification task.

The identification task instructions were to determine the emotion displayed on the face and were given the 3 alternative forced choice of "happy", "fearful", and "surprised". Participants made their response by pressing "f" (fear), "j" (happy), or "spacebar" (surprise) on the keyboard. Each image from each of the 3 continua was presented in random order a total of 4 times. Participants identified 132 images per block, 264 images total.

Pilot testing suggested that the sequential ABX discrimination task was too difficult so a delayed matching task was used. Participants viewed a fixation cross in the center of the screen for 250 ms to direct their gaze. They then viewed a face image from the continuum for 750 ms. This was followed by a blank screen (1000 ms) and two face images presented next to each other. Participants were asked to indicate which of the two following face images matched the original one they saw. Of the two following face images, one was always an exact match to the original image they viewed and the other was 3 steps away from it on the continuum. Pilot testing suggested that at smaller intervals (i.e., two steps) participants were at chance for discriminating the images. Participants saw all possible 3 step combinations blocked by model; 96 trials per block, 192 trials total.

Participants in the context and no context conditions completed the exact same tasks. Participants in the context condition saw two extra screens over the course of the experiment. Before each block began participants were presented with the original surprised image used in the creation of the morphed continua. This image was paired with a surprising story (see Figure 1 for example). The stories were designed to suggest either a fear surprise or a happy surprise. Participants read the stories before the block of trials with the model who was described in the story. Participants in the context condition saw one happy story and one fear story in a counterbalanced order between participants. Participants were instructed to think about the story while they did the experiment. After completing the experiment participants in the context condition were asked what surprising events took place in the context story they were shown at the beginning of each experimental block. All participants correctly reported the surprising events. Participants in the no context condition were instructed to complete the task as they had done during the practice trials.

Figure 1 about here

3.5 Results

Identification

Identification responses were analyzed using a chi square test of independence to determine if responses differed between conditions (context vs. no context) and continua (happy-surprise, happy-fear, and surprise-fear) across the possible responses (happy, fear, surprised). Responses differed across the context conditions, χ^2 (6, $N = 7920$) = 13.79, $p = 0.032$. Within each context condition responses also differed when comparing between the tested continua. For the happy valence context condition, χ^2 (6, $N = 2640$) = 1075.78, $p < 0.001$. For the fear valence context condition, χ^2 (6, $N = 2640$) = 1079.85, $p < 0.001$. In the no context condition, χ^2 (6, $N = 2640$) = 1051.15, $p < 0.001$. See Figure 2 for identification curves.

Figure 2 about here

Discrimination

Independent samples t-tests were performed to determine if there were differences in overall accuracy across the different conditions tested. Accuracy scores were not significantly different across any of the 3 context conditions (happy valence surprise, fear valence surprise, or no context), all t's < 1.14, all p's > 0.264. Further, accuracy did not differ between the continua that were tested, all t's < 1.64, all p's > 0.109.

Categorical Perception

To infer categorical perception we tested whether identification performance predicted where participants would have the highest accuracy on the discrimination task. For each condition the 50% identification point was determined. Where the 50% identification point was between two images on the continuum both images were taken as the 50% identification point. These points were used to create groupings of accuracy scores from the discrimination task. At each discrimination pair along the continuum accuracy was predicted to be either "peak" or "non-peak" based on identification performance. If the discrimination pair spanned the 50% identification point it was relabeled as "peak". If the discrimination pair was outside of the category boundary it was relabeled "non-peak". We then averaged accuracy across discrimination pairs depending in each of the new variables, “peak” and “non-peak”. These new averaged accuracy scores were then compared to assess categorical perception of the stimuli. Average accuracy was collapsed across the models as there were no significant differences between the two models presented in identification or discrimination. Discrimination accuracy for each continuum broken down by context condition can be seen in Figure 3.

Figure 3 about here

A 3 x 2 x 3 (continuum by predicted peak by context) mixed model ANOVA was conducted. Two of the measures were within-subjects factors: continuum (happy-surprise, happy-fear, surprise-fear) and predicted peak (peak, non-peak). Context (happy valance context story, fear valance context story, or no story) was a between-subjects factor. This analysis revealed a significant main effect of predicted peak ($F(1,57) = 71.27, p < 0.001$). The main effect of continuum ($F(2,57) = 1.63, p = 0.200$) was not significant. Interactions between continuum by context ($F(4, 114) = 2.54, p = 0.044$), continuum by predicted peak ($F(2, 114) = 17.22, p < 0.001$), and continuum by predicted peak by context ($F(4, 114) = 3.92, p = 0.005$) were all significant. An interaction between predicted peak by context ($F(2, 57) = 2.46, p = 0.094$) approached significance. The 3-way interaction between continuum, predicted peak, and context was further analyzed by splitting the data based on context and performing a follow up 3 x 2 repeated measures ANOVA (continuum by predicted peak). For the fear context there was a significant main effect of predicted peak ($F(1,38) = 45.45, p < 0.001$) and a significant continuum by predicted peak interaction ($F(2,38) = 14.51, p < 0.001$). For the happy context there was a significant main effect of predicted peak ($F(1,38) = 32.49, p < 0.001$) and continuum ($F(2,38) = 4.38, p = 0.019$) and a significant continuum by predicted peak interaction ($F(2,38) = 7.87, p = 0.001$). In the no context condition there was a main effect of predicted peak ($F(1,38) = 3.94, p = 0.028$) and continuum ($F(1,38) = 8.12, p = 0.010$), but no significant interaction.

Figure 4 about here

These analyses show that accuracy differed depending on the continuum being tested and whether the discrimination was peak or non-peak and also the context condition (see Figure 4). Follow up paired t-tests were performed to determine the source of our significant interactions. Paired t-tests were conducted between peak and non-peak accuracy for each continuum in the happy and fear context conditions. We applied the Bonferroni correction to each family of tests (.05/2 = .025) to control for the familywise error rate. In the happy valence context condition, peak and non-peak accuracy were significantly different for the happy-fear and surprise-fear continua ($t(19) = 5.26, p < 0.001$, $t(19) = 5.12, p < 0.001$) but not for the happy-surprise continuum ($t(19) = 0.75, p = 0.465$). In the fear valence context condition, peak and non-peak accuracy were again significantly different for the happy-fear and surprise-fear continua ($t(19) = 5.56$, $p < 0.001$, $t(19) = 7.47$, $p < 0.001$) but not for the happy-surprise continuum ($t(19) = -1.74$, $p = 0.099$).

3.6 Discussion

We investigated the effect of immediate context on categorical perception. We found evidence suggesting that context affects categorical perception; specifically, surprise stimuli are perceived categorically when a context is presented and when the images are threat relevant (in this case, fear faces are present); whereas there is no evidence of categorical perception when no context is given or the surprised expression is paired with happy. This is the first demonstration that context can influence categorical perception of emotional facial expressions.

Identification performance was similar with and without a context: the data suggest that people do not change the way they identify images from a continuum depending on the context they are given. This is unsurprising given that previous research has found surprise paired with other emotions to have a typical "s-shaped" identification curve.

In contrast, we found that discrimination performance differed between individuals who were provided with a context and those who were not. This suggests top-down processes can influence categorical perception. Top-down processes have been shown to alter perception in many domains, including emotion perception (Carroll & Russell, 1996). To our knowledge this is the first demonstration of a change in categorical responding in the domain of emotional facial expressions. This change is interesting because it was made with relatively simple alterations to the task. Participants were told to read a short story about a person's picture and to think about that story while they did the task.

One unexpected finding was that the valence of the context story did not matter; it was just the presence of a context story that changed perception of the surprise, fear, and happy expressions. It was also unexpected to find that perception was not categorical for the happy-fear continuum in the no context condition. Previous research has found this continuum to be perceived categorically. Our task combined the easily confused expressions surprise and fear in the same condition. Perhaps the difficulty of identifying and discriminating these expressions prevented individuals from making accurate discriminations in for all the expressions tested in that condition. Future research could explore this possibility by manipulating cognitive load while participants complete a discrimination task.

We chose to include stories with different valences to determine if there was something special about fear that was driving this effect. Our study did not support this interpretation; a context story that was either happy or fearful changed perception. It is possible that our happy and fear stories were not equated in arousal as the stories were not pre-tested for this. However, the presence of either story was associated with a change in perception for surprise-fear faces. We cannot know for sure if the type of story influences categorization but it does not seem to have played a major role in this experiment. Future studies might also include a neutral valenced context story as a control condition.

From an evolutionary perspective threats are particularly relevant because of the costs associated with them. Some researchers have suggested that negative emotions are 'over represented' in the emotion literature because the emotion system operates with a false alarm principle (Fredrickson, 1998; Nesse, 1990). Because a miss is so costly, the system will "take the hit" of over responding to situations that are only potentially threatening or dangerous. In emotion perception terms, missing the detection of a fear face may be so costly (i.e., a dangerous situation will not be avoided) that we will err on the side of detecting that fear face even when it does not truly exist. In our study, individuals perceived images including fear categorically when they were given a context for doing so. They responded to the context situation by employing categorical perception, which may be a more efficient way of processing expressions (Etcoff & Magee, 1992). Consistent with signal detection models, they did so only when the information was threat relevant. When the continuum did not include threat (it was happy-surprised) perception did not change. This may be further evidence supporting the false alarm principle for emotional facial expressions.

Future studies might further explore fear perception by looking at whether other emotion categories change in response to contextual information suggesting a threat. Several existing studies have found evidence that threatening faces and stimuli are processed more quickly than non-threatening (Krysko & Rutherford, 2009; Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001). The current findings are in line with the existing literature on privileged processing of threat.

We considered why it might be the case that perception changed only when surprise faces were paired with fear faces. There is some evidence from neuroimaging studies that may provide insight as to why fear might be processed differently from other emotional facial expressions. The strongest evidence comes from the many studies of emotion processing in the amygdala, in particular the involvement of the amygdala in processing fear or threat relevant stimuli (Adolphs, 2002; Adolphs, Tranel, Damasio, & Damasio, 1994; Morris et al. 1996). These studies show that damage to the amygdala results in specific deficits in recognizing fear expressions (Adolphs et al. 1994) and also that there is an activation of the amygdala to fear facial expressions in healthy participants (Morris et al. 1996). Further, the amygdala has been implicated in several stages of emotion processing from initial processing of visual information to later stages of processing and guiding of attention along with decision making processes (Ochsner, Bunge, Gross, & Gabrieli, 2002; Vuillleumier, Armony, Driver, & Dolan, 2001). These later stages are most relevant to a discussion of perceptual change: Ochsner et al. (2002) found that activation changed in several brain areas following reappraisal, suggesting the conscious efforts of participants to change their emotional perception had directly measurable consequences. These may be the kind of processes that are involved in changes in categorical perception. A change in categorical perception required two conditions to be met: the continuum included fear and the individual had enough information to make a meaningful judgment about the emotional expressions they were viewing (we gave them a story or reason for those expressions). Appraisal of situations involving fear may lead to a "flagging" of faces as important for quick and accurate processing.

Further, the link between attention and emotion processing has been found at several different levels of emotion processing in the brain (Adolphs, 2002). Gray, Braver, and Raichle (2002) found that emotional state influenced task performance as well as brain activation. Yamasaki, LaBar, and McCarthy (2002) found fMRI evidence showing that attention and emotion are separate at some stages of processing but are integrated at others. Together, these findings suggest that attention and emotion are closely tied together during processing in the brain. These emotional states can influence task performance in ways that are behaviorally quantifiable. The role of attention and emotion in processing is important to consider when evaluating the results of any task. Attention may provide a mechanism for this perceptual change. The current finding of top-down processing in emotion perception is consistent with this work.

In conclusion, results from this study show that context has an effect on the visual perception of emotional facial expressions. A surprise-fear and happy-fear continua were perceived categorically only in the case where a context story was provided for the surprised face. This is the first evidence that we know of showing top-down processing changing categorical perception for emotional facial expressions.

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3.8 Table & Figures

Table 1

Participant Group Membership

Version	Block	Model	Valence	Number of participants: Context	Number of participants: No context
A	1	Male	Fear Surprise	10	10
	2	Female	Happy Surprise		
B	1	Male	Happy Surprise	10	--
	2	Female	Fear Surprise		
C	1	Female	Happy Surprise	10	10
	2	Male	Fear Surprise		
D	1	Female	Happy Surprise	10	--
	2	Male	Fear Surprise		

Note. In the 'no context' condition version A and B are the same (as are C and D) because the order of context story is counterbalanced in the 'context' condition. Ten participants were run per condition.

Figure Captions

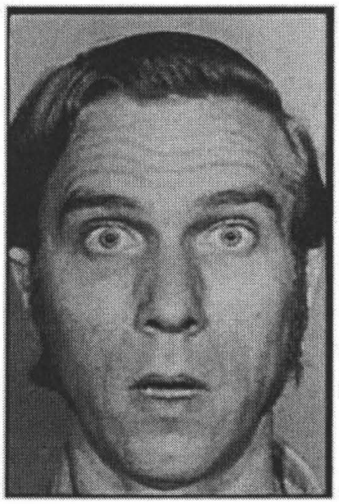
Figure 1. Example context stories (fear and happy valence).

Figure 2. Percent response on identification task for each continuum. a) happy-surprise continuum, b) happy-fear continuum, c) fear-surprise continuum.

Figure 3. Percent correct plotted for each continuum with labels identifying the between category and within category discrimination pairs. a) happy-surprise continuum, b) happy-fear continuum, c) fear-surprise continuum.

Figure 4. Percent correct comparisons between peak and non-peak discrimination pairs for each continuum. a) happy-surprise continuum, b) happy-fear continuum, c) fear-surprise continuum.

Figure 1


Mike was making dinner after a long day at work. He opened and shut cupboards absentmindedly while he set the table. When he reached up to get a plate a large brown spider jumped down from the shelf at him. Mike was surprised and fearful until he realized it was harmless.
Press any key to continue.

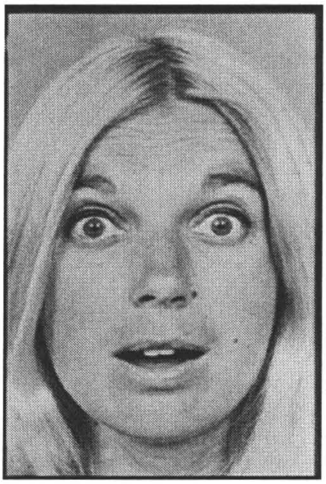
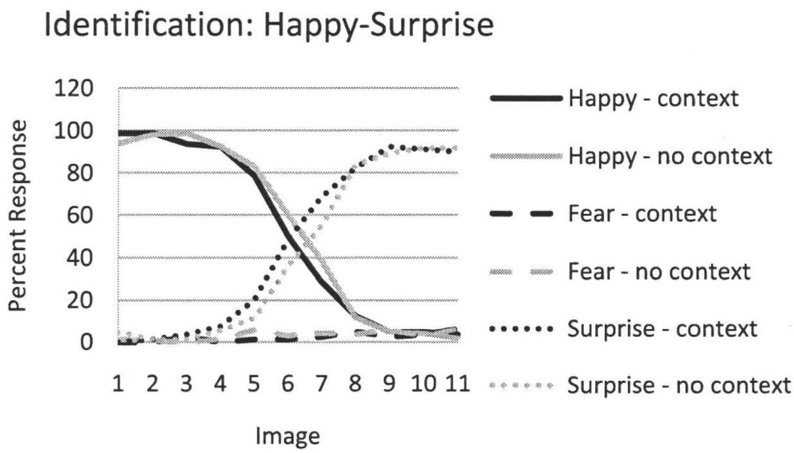
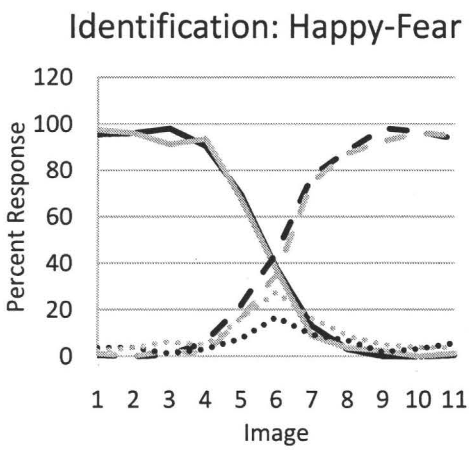

Angela got off the bus after a long day of work. She walked up to the door and walked inside. Instantly she noticed something was different. Fifteen of her friends jumped out from various hiding places and shouted "happy birthday"! Angela was surprised and happy that her friends remembered her upcoming birthday.
Press any key to continue.

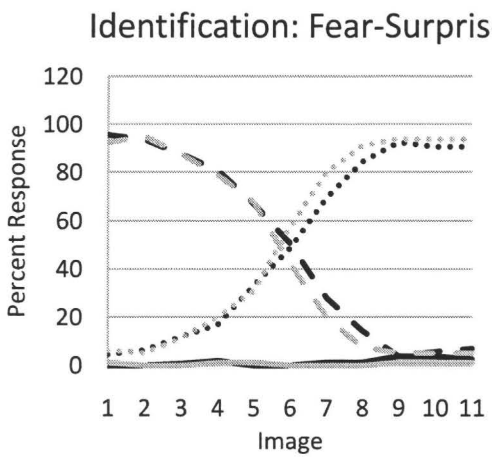
Figure 2


Identification: Happy-Surprise
120
100
80
60
40
20
0
Percent Response
1 2 3 4 5 6 7 8 9 10 11
Image
Happy - context
Happy - no context
Fear - context
Fear - no context
Surprise - context
Surprise - no context

a)

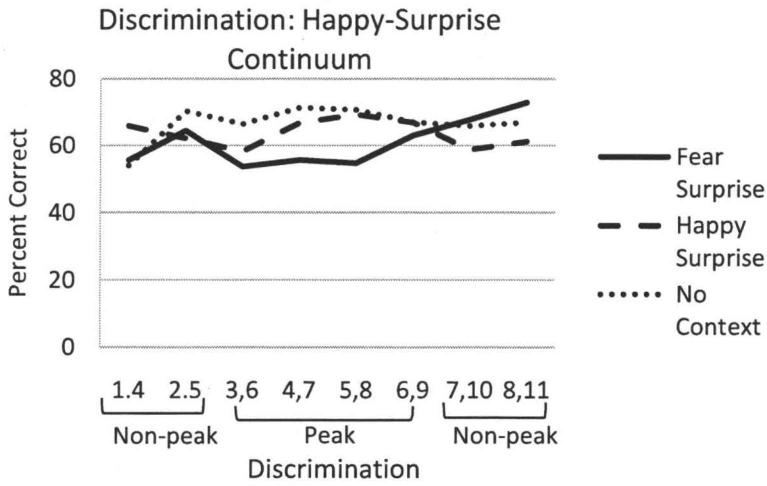

Identification: Happy-Fear
120
100
80
60
40
20
0
Percent Response
1 2 3 4 5 6 7 8 9 10 11
Image

b)

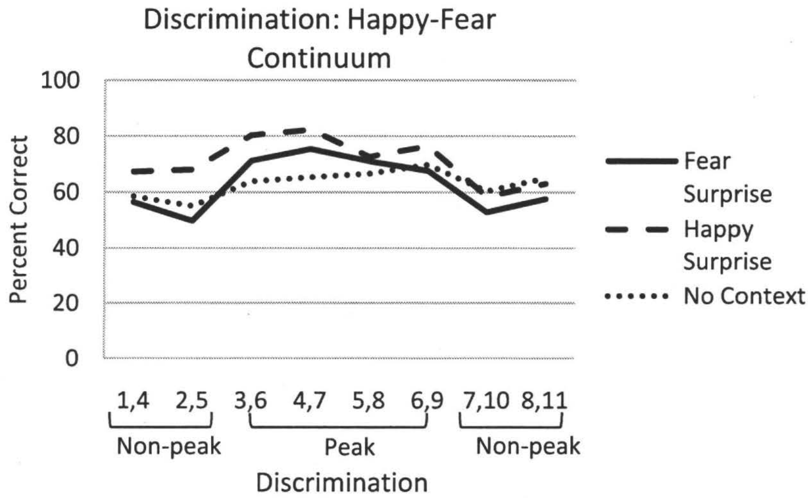

Identification: Fear-Surprise
120
100
80
60
40
20
0
Percent Response
1 2 3 4 5 6 7 8 9 10 11
Image

c)

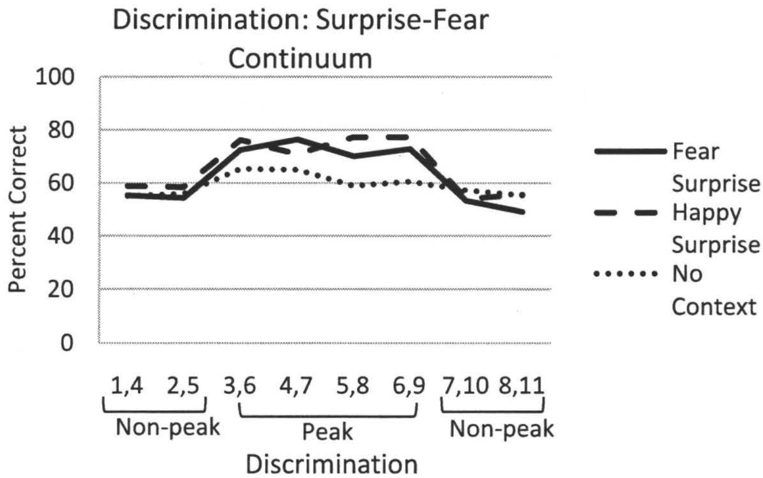
Figure 3


Discrimination: Happy-Surprise Continuum
80
60
40
20
0
Percent Correct
Fear Surprise
Happy Surprise
No Context
1.4
2.5
3,6
4,7
5,8
6,9
7,10
8,11
Non-peak
Peak
Non-peak
Discrimination

a)

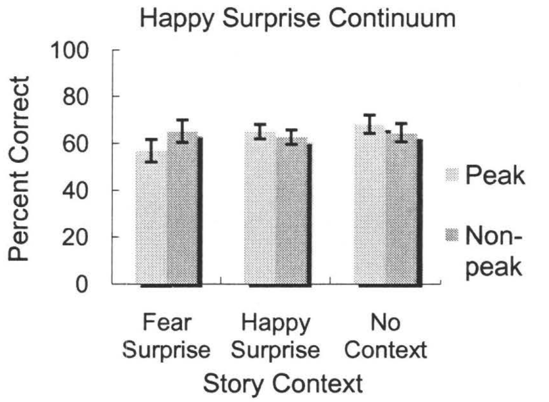

Discrimination: Happy-Fear Continuum
100
80
60
40
20
0
Percent Correct
Fear Surprise
Happy Surprise
No Context
1,4
2,5
3,6
4,7
5,8
6,9
7,10
8,11
Non-peak
Peak
Non-peak
Discrimination

b)

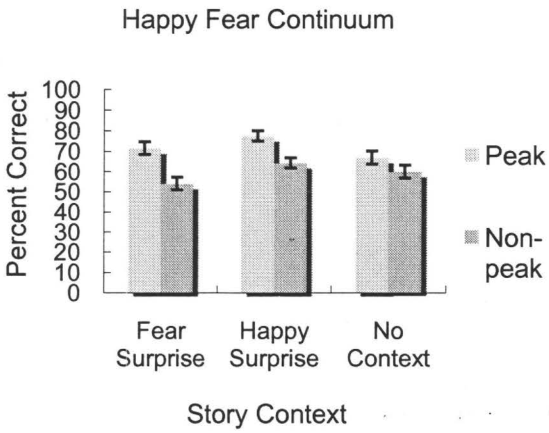

Discrimination: Surprise-Fear Continuum
100
80
60
40
20
0
Percent Correct
Fear Surprise
Happy Surprise
No Context
1,4
2,5
3,6
4,7
5,8
6,9
7,10
8,11
Non-peak
Peak
Non-peak
Discrimination

c)

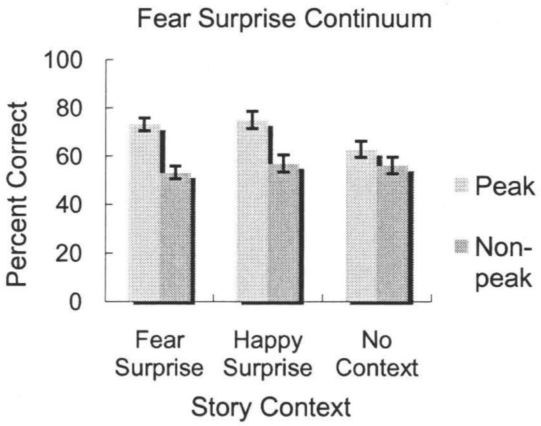
Figure 4


Happy Surprise Continuum
100
80
60
40
20
0
Percent Correct
Peak
Non-peak
Fear Surprise
Happy Surprise
No Context
Story Context

a)


Happy Fear Continuum
100
90
80
70
60
50
40
30
20
10
0
Percent Correct
Peak
Non-peak
Fear Surprise
Happy Surprise
No Context
Story Context

b)


Fear Surprise Continuum
100
80
60
40
20
0
Percent Correct
Peak
Non-peak
Fear Surprise
Happy Surprise
No Context
Story Context

c)

CHAPTER 4

CATEGORICAL PERCEPTION OF EMOTIONAL FACIAL EXPRESSIONS IN PRESCHOOLERS

4.1 Preamble

This chapter investigates a small part of the developmental trajectory of categorical perception of emotional facial expressions. Perception of emotional facial expressions is an important tool for guiding behavior in social situations. While it is well known that adults perceive emotional facial expressions categorically [See Introduction 1.1 & 1.4 for full review], comparatively little research has investigated the phenomenon in children. Children, ostensibly, would benefit from quick and accurate perception of emotional expressions in much the same way that adults do. For this reason an investigation into the development of this phenomenon is an important contribution to the literature.

For infants and children we define categorical perception in the same way we would for adults; as greater accuracy in discriminating pairs of stimuli when they cross a category boundary compared to pairs that are within a perceptual category. This definition is useful for comparing performance in domains we know that adults have categorical perception for, such as emotional facial expressions. Whether the infant's brain is immediately able to process certain types of information in categories or whether this proclivity is later developing is unknown. However, this general mechanism could be the fundamental basis of perception leading to successful parsing of the visual, auditory, olfactory, tactile, and gustatory signals we process when we perceive.

A fundamental problem for young children is figuring out how to interact with the variety of known and unknown individuals they will come into contact with in their environment. Very young infants largely avoid this problem because their primary caregivers move them around and "choose" their social interactions for them. As children become older and begin to move around on their own they are increasingly responsible for choosing whom to interact with and whom to avoid (and also which situations are safe and which are not). Perception of emotional facial expressions may be an important part of this decision-making process.

In addition, individuals can use the expression on others' faces to determine how to react in ambiguous situations. The social referencing literature suggests that infants can use this information for this purpose as they approach one year of age. Infants modify their behavior depending on the expression on the mother's face in response to ambiguous situations (Sorce, Emde, Campos, & Klinnert, 1985). Categorical perception of emotional facial expressions may facilitate these decisions in young children giving them more information for navigating social situations.

Development has been and is currently an important and instructive area of the categorical perception literature. The investigation into development of categorical perception is rooted in looking at categorical perception in speech

(Repp, 1984). Infants segment auditory information into the same meaningful pieces that adults use when perceiving speech (e.g., Eimas, Miller, & Jusczyk, 1987; Kuhl, 1979; Repp, 1984). This early segmentation may be one of the building blocks of later speech perception. Color perception has also been investigated in young infants with an emphasis on determining whether infants perceive color in the same broad categories as adults. Infants use similar color categories as adults from a young age (4 months) suggesting from at least this point categorization guides color perception (Bornstein, Kessen, & Weiskopf, 1976). Investigation into categorization of other domains (such as emotional facial expression as was done here) can tell us broadly about infants' perceptual system and how infants solve the perceptual problem of organizing incoming information.

Categorical perception may be important beyond simply understanding other's speech or emotional expressions. Indeed, categorical perception may be a building block of perception in many domains (Repp, 1984). One of the key problems that organisms face is determining how to organize a vast amount of information into efficient and meaningful pieces of information. This problem is of particular importance for development because as adults these individuals will need to sort many environmental inputs into information they can use first for survival and later for general fitness, including reproduction.

In the following paper I explored categorical perception in 3.5-year-olds by creating a morphed continuum of emotion faces, and testing discrimination and identification performance. In the discrimination task two adjacent images from the continuum were presented and participants indicated whether the two images "felt the same" or "felt different". In the identification task images were presented individually and the participant was asked to label the emotion displayed on the face (i.e., "Does she look happy or sad?"). Results suggest that 3.5-year-olds have the same category boundary as adults. They were more likely to report the image pairs felt "different" at the image pair that crossed the category boundary. These behavioral results suggest that 3.5-year-olds perceive happy and sad emotional facial expressions categorically, as adults do.

4.2 Abstract

Adults perceive emotional facial expressions categorically (e.g., Etcoff & Magee, 1992). In this study, we explored categorical perception in 3.5-year-olds by creating a morphed continuum of emotional faces, and testing preschooler's discrimination and identification of them. In the discrimination task participants indicated whether two examples from the continuum "felt the same" or "felt different". In the identification task images were presented individually and the participant was asked to label the emotion displayed on the face (i.e., "Does she look happy or sad?"). Results suggest that 3.5-year-olds have the same category boundary as adults. They were more likely to report the image pairs felt "different" at the image pair that crossed the category boundary. These results suggest that 3.5-year-olds perceive happy and sad emotional facial expressions categorically, as adults do. Categorizing emotion could have potentially large benefits to the child in avoiding costly situations where fitness might be reduced.

4.3 Introduction

Emotional facial expressions convey information to others about internal states. The perception of emotional expressions may serve important evolutionary functions. Perception is specialized to solve specific environmental problems including decision-making that may be informed by another's facial expression (Cosmides & Tooby, 2000; Fredrickson, 1998; Nesse, 1990; Rutherford, Chattha, & Kryško, 2008). Categorical perception is important because it allows for quick decision making about possibly ambiguous situations or cues in the real world (Harnad, 1987). Automatic categorization can inform peoples' behavior more efficiently than could a system that relies on continuous perception. Not only is this useful for adults; there are benefits for children in having categorical perception of emotional facial expressions as they navigate a rich and complex social world, such as using facial expressions to change behavior in situations of uncertainty (e.g., Sorce, Emde, Campos, & Klinnert, 1985). Children who use categories would be at an advantage because their behavior would be determined by faster and more efficient sources of social information. While research has focused on the adaptive role of emotional facial expressions in adults, few studies have examined how emotional facial expressions are perceived and function in young children (Sorce et al., 1985). The current study tests whether preschoolers' perception of emotional facial expressions is categorical.

Categorical Perception of Emotional Facial Expressions

Adults perceive basic emotional facial expressions categorically, (Calder, Young, Perrett, Etcoff, & Rowland, 1996; de Gelder, Teunisse, & Benson, 1997; Etcoff & Magee, 1992; Young, Rowland, Calder, Etcoff, Seth, & Perrett, 1996) that is, when tested under laboratory conditions identification performance predicts discrimination performance. In a typical categorical perception experiment participants complete two tasks: identification and discrimination. The stimuli used in each task are identical; two exemplars (i.e., two initial emotional expressions) that have been morphed from one to the other result in a number of intermediate instances that are equally physically distant from each other.

In the identification task each image from the continuum is presented in a randomized order and the participant must label it as one category exemplar or the other. The location on the continuum where the participants' identification is equally likely to be one or the other category exemplar is the 50% identification point. It is at this point that discrimination accuracy is predicted to be highest if the stimuli are indeed perceived categorically. On either side of this conceptual boundary the stimuli are perceptually grouped into one category, making the discrimination between groupings ostensibly easier. In the discrimination task, pairs of stimuli from the continuum are presented and accuracy in discriminating the pairs is measured in one of a few types of discrimination paradigms. Adults show higher accuracy on between category comparisons than within category comparisons and this accuracy difference can be predicted based on performance on an identification task, suggesting categorical perception for these stimuli (Harnad, 1987; Repp, 1984). Categorical perception has been found for basic emotional expressions, but studies have not been done on other expressions. Further, not all studies of categorical perception are in 100% agreement. Etcoff and Magee (1992) found that all basic emotions except surprise were perceived categorically. In contrast, Young, Rowland, Calder, Etcoff, Seth, and Perrett (1997) tested all pairs of basic emotions for categorical perception and found evidence that surprise was perceived categorically. These inconsistencies have yet to be resolved in the published literature.

The Development of Emotion Perception

Perception of facial expressions develops over the first two years of life. Only limited evidence suggests that infants younger than 2 months of age are able to discriminate emotional facial expressions. Field, Woodson, Greenberg, and Cohen (1982) found that an observer who could not see the posed expression could guess what the posed expression was at greater than chance levels by looking at the face of an approximately 36 hour old infant suggesting that even very young infants imitate some facial expressions. Infants tested between 31 and 87 hours after birth were found to look longer at a happy face compared to a fearful face (Farroni, Menon, Rigato, & Johnson, 2007). Around 2-3 months of age infants begin to show evidence that they can discriminate between emotional facial expressions. At 10 weeks infants sometimes change their behavior in response to changes in the mother's expression, such as expressing joy in response to their mother showing the same expression (Haviland & Lelwica, 1987). By 3 months of age infants begin to discriminate smiling from frowning faces (Barrera & Maurer, 1981) and happy from surprised faces (Young-Browne, Rosenfeld, & Horowitz, 1977). By 4 months of age joy expressions are looked at longer than anger or neutral expressions, suggesting infants discriminate these expressions (La Barbera, Izard, Vietze, & Parisi, 1976). By 7 months of age infants can discriminate happy and fear expressions readily (Nelson, 1987; Nelson, Morse, & Leavitt, 1979).

Between 4 and 7 months of age it appears that emotion perception undergoes significant development. Before this time period infants may use physical differences to make expression discriminations (Nelson, 1987). By 7 months, however, infants discriminate emotions that vary along other dimensions (i.e., they generalized an emotion across individuals of different identities) suggesting that the infant perceives emotional expression per se, independent of specific images (Bornstein & Arterberry, 2003; Nelson, 1987).

Finally, clear evidence that the perception of emotional facial expressions is functional for infants (they have an effect on infant behavior) comes from a large body of social referencing literature. Use of cues such as emotional facial expressions is unnecessary early in life because the infant is unable to locomote and parents are responsible for the safety of the infant. However, as the infant approaches 1 year of age and begins to explore the environment on its own other cues become more important and may be adaptive. Nine month old infants play less with toys when their mother displays a sad facial expression compared to a joyful expression (Termine & Izard, 1988). By 1 year of age infants modify their behavior (they cross or refuse to cross a visual cliff) in response to posed expressions (joy or fear, respectively) from the mother (Sorce, Emde, Campos, & Klinnert, 1985).

Beyond the first year and into the second year of life recognition and discrimination of emotional facial expressions improves with increasing age (Batty & Taylor, 2006; Camras & Allison, 1985; Herba, Landau, Russell, Ecker, & Phillips, 2006; Herba & Phillips, 2004; Russell & Widen, 2002). Children as young as 2 choose correct emotion labels as well as correct images of emotional facial expressions at above chance levels when they are given a story describing an emotion inducing event (Bullock & Russell, 1985; Russell & Bullock, 1986; Russell & Widen, 2002). For images of faces portraying an emotion children are most accurate at identifying happy expressions and next most accurate at identifying sad expressions. Children range in accuracy with identification of other emotional expressions but tend to do the most poorly with disgust and surprise (Camras & Allison, 1985; MacDonald & Kirkpatrick, 1996; Stifter & Fox, 1987).

Further work has been done with young children investigating whether the categories of emotion are structured similarly to those of adults. Russell and Bullock have conducted several studies examining the ways in which young children group emotional facial expressions based on similarity. Based on these similarity sorting tasks and application of multidimensional scaling they found that children (2- to 5-year-olds) and adults group emotions similarly and there are two dimensions that come out of these groupings for both children and adults (Bullock & Russell, 1984; Russell & Bullock, 1985; Russell & Bullock, 1986). Bullock and Russell found two dimensions, pleasantness and arousal, for adults as well as 2 year olds, the youngest group they tested. These data suggest that children as young as 2 and adults may be processing emotional facial expressions similarly.

These similarities notwithstanding, several studies have found important differences between the processing of facial expressions between adults and children. Russell and Widen (2002) found that preschoolers are able to label emotions accurately at greater than chance levels; however they are still less accurate than adults doing the same task. Five- to eleven-year-olds are less accurate at discriminating emotional expressions depending on the emotion. Anger and fear faces have lower discriminability for 5 and 7 year olds while happy and sad faces do not (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007). The largest improvements in performance discrimination occur between 5-6 and 7-8 years of age, but have not reached asymptote by 10 years of age for some expressions (Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000). In addition, children may be at a particular disadvantage when the expressions presented are not intense. Gao & Maurer (2009) found that 5-, 7-, and 10-year-olds were less sensitive to expressions of sadness and fear than adults, especially when those expressions were less intense. Brain activation patterns suggest that development continues into the teenage years for recognition and discrimination of emotional expressions (Batty & Taylor, 2006).

Categorical Perception in Children

There is evidence that suggests categorical perception of color in infants as early as 4 months of age based on differential habituation recovery (Bornstein, Kessen, & Weiskopf, 1976). In this study infants looked longer at color comparisons that were between two adult categories than those that were within an adult color category. When 3 and 4 year olds identify colors from a spectrum the boundaries (the point where they switch from naming one color to another) are similar to those of adults (Raskin, Maital, & Bornstein, 1983). In addition, adults and children become more accurate and consistent with color naming with age (Raskin et al., 1983). Color naming errors are greater for colors that are perceptually close rather than distant for preschoolers (Pitchford & Mullen, 2003). These color naming studies suggest that color categories are initially broad and are refined as children develop. Finally, toddlers from a western culture and from a tribal society in Africa were compared for differences in categorical perception. Toddlers (2 to 4 years of age) appear to have demonstrated categorical perception of color in both cultures regardless of color term knowledge (Franklin, Clifford, Williamson, & Davies, 2004). Toddlers were presented with a discrimination task in the form of choosing matching sweaters for cut-out bears. After briefly viewing a bear wearing a colored sweater, two sweaters (one exactly matching the original sweater worn by the bear and one that was either a non-match within category color or a non-match between category color) were presented to the child. Children chose the correct match when the foil sweater color was between category more often than when it was a within category color. In this study between and within color pairs were chosen based on adult color categories. Franklin et al. (2004) asked children to identify the colors of the sweaters after the discrimination task, however full continua consisting of more than three colors were not tested and the identification task was not directly compared to the discrimination data. This failure prevents making a clear conclusion of categorical perception in this study.

Only one known study documents possible categorical perception of emotional facial expressions in an age group other than adults. Kotsoni, de Haan, and Johnson (2001) present evidence for categorical perception of emotional facial expressions in 7-month-old infants. They use a preexisting preference of 7-month-old infants to look longer at faces displaying fear to identify the category boundary on a happy-fear continuum. They then tested naïve infants on a visual preference discrimination task. They showed infants a face image from one side of the hypothesized boundary and familiarized them with that face. They then showed the infant a face image that was between category and an image that was within category and measured looking time. Infants looked longer at between category images only when they had been familiarized with "happy" faces but not when they were familiarized with "fear" faces. This study failed to show complete identification of the test stimuli. In addition, discrimination performance was only greater for between category comparisons in one direction on the continuum. The authors suggest that this asymmetry is due to infants' preference for looking at fear faces at this age, however this preference confounds the study because categorical perception does not occur solely for categories that individuals have a preference for. These problems warrant further investigation into categorical perception in infants.

The current study was designed to investigate identification and discrimination performance in young children to determine whether they show categorical perception of emotional facial expressions. Our study goes beyond previous research because it includes both identification and a discrimination tasks and compares the results of these tasks to adult data gathered using the same stimuli and procedure. We tested 3.5-year-olds because previous research suggests that this age group is able to discriminate a number of facial expressions (Herba, Landau, Russell, Ecker, & Phillips, 2006; Herba & Phillips, 2004; Russell & Bullock, 1985). In addition they are able to produce labels for different emotional expressions, allowing us to test identification (Camras & Allison, 1985; Stifter & Fox, 1987).

4.4 Methods

Participants

Sixteen 3.5-year-olds (6 females, 10 males, *mean age* = 42.64 weeks, *SD* = 0.53) were recruited through the McMaster psychology subject pool. Children received a small toy as compensation when they completed the study. Three additional participants' data were not analyzed due to technical problems (2) or because the child did not complete the task (1). Preschooler data was compared to that of 12 adults (8 females, 4 males, *mean age* = 18.67 years, *SD* = 0.78) who were current McMaster University undergraduates. Adult participants were recruited through the McMaster University psychology participant pool and were given partial course credit for their participation.

Stimuli

Stimuli in this experiment consisted of images from a morphed continuum of emotional facial expressions. The endpoints of this continuum were black and white photographs from Ekman and Friesen's (1976) *Pictures of Facial Affect*. One individual from the set was used (C) and a continuum spanning happy to sad was created from these images.

Morphed continua were created using Morpheus v1.85 software. The software requires the user to supply matching locations on two images and then interpolates at the desired interval to create intermediate images. The resulting continuum included four intermediate images and two endpoint (original) photographs for a total of six images. The original Ekman and Friesen (1976) images were altered using Adobe Photoshop 7.0 to remove the hairline and outer edges of the images and to make all images a consistent brightness (see Figure 1).

Figure 1 about here

Apparatus

The task was completed on a GVision P19BH-AE touch screen monitor. The experiment was programmed in Java using J2SE 1.5 and run on a MacBook Pro using Max OS X.

Procedure

All participants completed two tasks: discrimination and identification. Each of these tasks was preceded by training on the procedure using cartoon face images with happy and sad expressions. Training was designed to ensure that they understood the instructions. Children were seated at a small table with the experimenter next to them approximately 25 cm from the screen. The parent was seated behind the child a short distance away. The parent was able to see the child's choices but the child was not able to see the parent's reaction. Adult participants were also seated approximately 25 cm from the screen. Adults completed both discrimination and identification tasks, but did not do the training part of the procedure.

Discrimination.

The discrimination task was always the first task that the children and adults performed so that they were not primed from the identification task to think about the stimuli that they were discriminating using emotion labels. Training began by asking the children if they could "help sort" some faces. The touch screen was blank except for two cartoon houses. The houses were centered vertically on the screen and were located 2 cm from the left and right edge of the monitor. Each house was 5.5 cm square (as shown in figure 2b). The experimenter showed the child that the monitor was a touch screen by demonstrating touching one of the houses. The experimenter then encouraged the child to "try it". The experimenter explained the task directions. She said that people who *feel the same* go in one house (pointing to the house) while people who *feel different* go in the other house (again, pointing to the appropriate house). The child was then asked to touch the house were "people who feel the same go" and where "people who feel different go". Next, two cartoon faces appeared in the center of the screen (between the two houses). These faces were either both happy, both sad, or a combination of one happy and one sad. When the faces were both happy or both sad, the particular cartoons shown were two different happy faces or two different sad faces. This cartoon difference was designed to ensure that children were not matching strictly on perceptual similarity, and were using the emotion information in the face to make the sorting decision. Children were prompted to complete the task by the experimenter asking "How does he feel? And how does he feel? So they feel…" allowing the child to fill in whether they were "the same" or "different".

When the child correctly completed four same/different categorizations the test stimuli were presented. The test stimuli were the images from the morphed happy to sad continuum. Faces were presented between the two houses centered vertically. Each face was 5.8 cm by 7 cm and subtended 13.2° x 15.9°. They were separated around the center of the screen by 5.5 cm (see Figure 2). Every possible adjacent pair comparison from the continuum was presented in a different randomized order for each participant (1-2, 2-3, 3-4, 4-5, 5-6). In addition to these pairings, 3 control trials were presented randomly (1-1, 6-6, 1-6). These control trials were included to evaluate whether the participants understood the task.

Identification.

Following the discrimination task children performed an identification task. Again, two houses were located at the two edges of the monitor in the same location as they were in the discrimination task but only one face image appeared, as shown in figure 2a. The experimenter explained to the child that they were going to sort one face at a time and that people who were *happy* would go in one house while people who were *sad* would go in the other house. Again, the experimenter pointed to the correct houses for categorizing the happy and sad images and then had the child point to each house correctly. Training required the child to categorize four cartoon images (two happy, two sad) by touching the correct houses.

When the child correctly categorized the cartoon face images the test stimuli were presented. A single face image from the continuum was presented (in a different randomized order for each participant) in the center of the screen (see Figure 2). Each face was 11 cm by 14.5 cm and subtended 24.8° x 32.3°. Faces in the identification task were larger because only 1 image was shown at a time and therefore more screen space could be used. The larger size of face images allowed for more detail to be seen in the images such that individuals had the most information possible to make a categorization. Each of the images from the continuum was presented a single time. Adult participants completed only the test portion of the identification task. They were asked to put faces that looked happy in one house and faces that looked sad in the other.

Figure 2 about here

4.5 Results

Previous research shows that adults perceive emotional facial expressions categorically. We wanted to ensure that our stimuli and our procedure could be used to determine if adults show evidence of categorical perception. We used the exact same stimuli and task (without the training procedures) on a group of 12 adult participants (McMaster University undergraduates). Identification and discrimination task performance can be seen in Figure 4 (A and B, respectively). We performed a "peak" vs. "non-peak" analysis on the individuals' results (see *Categorical Perception* section below for details of analysis). We found that peak (*mean percent response "different"* = 83%) and non-peak (*mean percent* *response different* = 15%) percent response "different" differed significantly, $t(11) = 3.89, p < 0.01$.

Identification

The identification results show a similar pattern of response to that of adults. Three-and-a-half-year-olds consistently categorize images 1 and 2 as sad (100% response sad), image 3 and 4 as ambiguous (respectively 62.5% response happy, 37.5% response sad and 25.0% response happy, 75.0% response sad), and images 5 and 6 as happy (100% response happy). These results suggest that for three-and-half-year-olds the category boundary between happy and sad lies between the third and fourth image on the six image continuum (see Figure 2a).

Discrimination

We used a "same-different" categorization to assess discrimination performance on these morphed images. We found that percent response "different" was low for pairs 1-2, 2-3, and 5-6. Percent response "different" was relatively higher for the 3-4 and 4-5 image pairs (see Figure 2b).

Figure 3 about here

Categorical Perception

To infer categorical perception we compared the identification and discrimination performance of our three and a half year olds. We created two groups of scores based on the identification results. Results from the identification task suggest that the category boundary was between images 3 and 4 for most participants. However, because discrimination pairs included images 3 and 4 in the pairs 2-3, 3-4, and 4-5 we chose to analyze our data by looking at the 50% identification point for each participant. To do this we compared each individual's 50% identification point to their discrimination accuracy and created two new variables. The first was called "predicted peak". This variable was the discrimination accuracy of the pair that was predicted to be crossing the category boundary based on the identification task. For example, if an individual labeled images 1, 2, and 3 as happy and 4, 5, and 6 as sad we would predict that the category boundary would lie between images 3 and 4 for that individual. We categorized accuracy for the image pair 3-4 from the discrimination task as our new variable "predicted peak". This procedure was repeated for all participants. Next we took the remaining discrimination pairs (in our example above, 1-2, 2-3, 4-5, 5-6) and averaged the accuracy for each of those remaining discriminations and called this average "predicted non-peak". We then compared accuracy using a paired samples t-test between predicted peak and predicted non-peak. If perception is categorical we expect that predicted peak pairs will be discriminated more accurately than predicted non-peak pairs. If perception is not categorical then there is no reason to believe any pair would be discriminated more accurately than any other and our predicted peak variable should have a similar accuracy to predicted non-peak. We tested these two groups of scores using a paired samples t-test and found that peak (*mean accuracy* = 56%) and non-peak (*mean accuracy*

= 23%) accuracy differed significantly, $t(15) = 2.15$, $p = 0.02$. All participants correctly discriminated the control pairs (1-6, 1-1, 6-6) suggesting that preschoolers understood our task.

Figure 4 about here

4.6 Discussion

This is the first study of categorical perception of emotional facial expressions in preschoolers with both identification and discrimination data. This is an important contribution to the developmental literature because categorical perception can only be inferred when identification has been compared to discrimination. Three-and-a-half-year-olds show clear evidence of categorical perception of happy and sad emotional expressions; they were more likely to say that the face pairs "felt different" when the pair included images at the category boundary (as determined by the identification task). Furthermore, identification performance on morphed images from the continuum we tested (happy-sad) is similar to how adults perform on the exact same task. The only other developmental data on categorical perception of emotional facial expressions comes from one study involving 7-month-old infants where only discrimination was assessed (Kotsoni, de Haan, & Johnson, 2001). Our results clearly demonstrate categorical perception in preschoolers using the accepted standard of comparing identification to discrimination performance on emotional face images.

Three-and-a-half year olds identify the two images on the happy end of the continuum as 100 percent happy, and the two images on the sad end of the continuum as 100 percent sad. The third and fourth images on the six image continuum are ambiguous; approximately half of our participants identified them as happy and half as sad. These results suggest that the happy-sad category boundary is at approximately this location for preschoolers and adults. Discrimination performance appears qualitatively similar as well.

It is not possible to determine, based on these results, whether categorical perception in young children operates the same way that it does in adults because the current experiment did not explore the mechanism underlying the perception. Preschoolers may be using different criteria than adults to determine the expression on a face, such as relying on the eye region over the mouth for happy and sad expressions, as adults and older children do (Sullivan & Kirkpatrick, 1996; Schyns, Bonnar, & Gosselin, 2002). Eye tracking and brain activation studies on infants and young children identifying emotions would provide more information on these mechanisms. However, there are benefits to categorical perception that are the same between young children and adults. Three-and-a-half-year-olds are mobile and have social interactions with both adults and children. They would benefit from quick decision-making in social situations on whether approach or avoidance is the best strategy. Categorizing even subtle cues of emotion could have potentially large benefits to the child in avoiding costly situations where fitness might be reduced. For these reasons it is unsurprising that we would find categorical perception in young children.

Future studies will examine other continua of emotional facial expressions. We tested the happy-sad continuum. Our rationale for testing this continuum was that these two expressions are easiest for young children to identify (Camras & Allison, 1985) so we would not be complicating our task by including expressions that might be difficult for young children to understand. Furthermore, we wanted to simplify the task, placing minimal cognitive demands on the children. As we test younger age groups in the future we wanted the task to be as easy to understand as possible. Because we found evidence of categorical perception for these two expressions in 3.5-year-olds, it would be useful to determine whether this age group also shows categorical perception for other basic emotion pairs, as adults do.

Future studies will also include more steps in the tested continua. In studies of adult categorical perception the continuum typically includes 10 steps. We chose to reduce the number of morphs that our participants would see. We kept the overall number of trials low to keep the task within the child's attention span. In addition, we assumed that if children's categories were different from those of adults they would likely be broader. Our use of fewer images in the continuum would still capture the boundary if this were the case because each image in the continuum is more distinct from its neighboring images; a greater number of steps in a continuum mean each image is more similar to the next. The smaller continuum resulted in less precision when locating the category boundary.

Our next steps will be to examine categorical perception in 3-year-olds and possibly test younger children to determine if categorical perception is present even earlier for emotional facial expressions. Further, other emotion pairs will be tested to determine if categorical perception of emotional facial expressions is a robust phenomenon in young children as it is for adults. We will examine how children perceive expressions that they are unable to explicitly label and describe. If these expressions are perceived categorically it will suggest that the child's perceptual system is designed to process certain inputs in a particular way, even if the child has not yet developed an explicit verbal understanding of those expressions.

4.7 References

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4.8 Figures

Figure Captions

Figure 1. Morphed continuum (happy-sad) created using Ekman & Friesen (1976) Pictures of Facial Affect. Images 1 and 6 are original photographs. Two through 5 are intermediate morphs.

Figure 2. Screenshot of identification (A) and discrimination (B) tasks as displayed on the touch screen monitor.

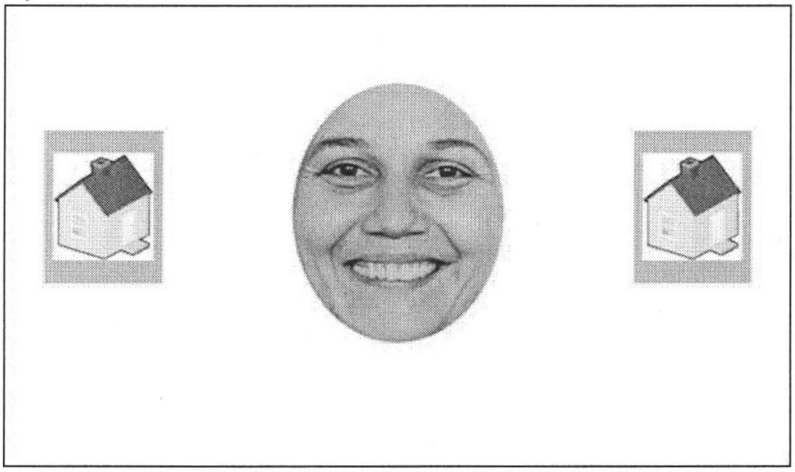
Figure 3. Overall results from identification and discrimination tasks with 3.5 year olds. A) Percent of children responding "happy" and "sad" on the identification task. B) Percent of children responding "feels different" for each image pair on the discrimination task.

Figure 4. Overall results from identification and discrimination tasks with adults. A) Percent of adults responding "happy" and "sad" on the identification task. B) Percent of adults responding "feels different" for each image pair on the discrimination task.

Figure 1

Figure 2

A)



B)

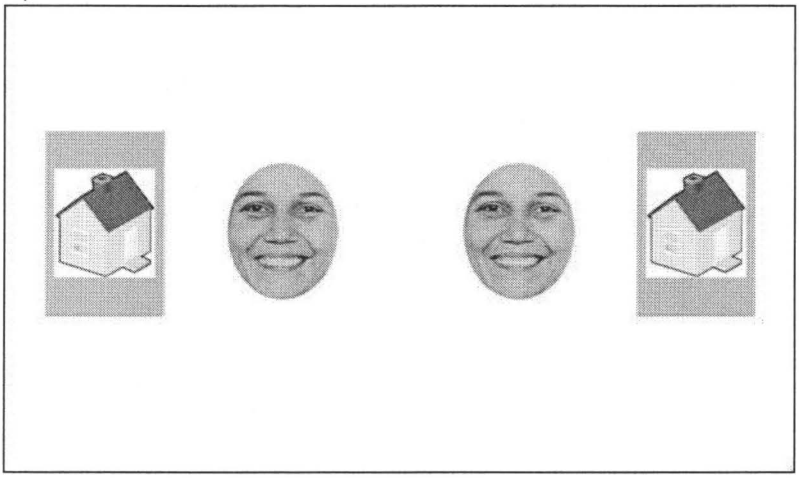
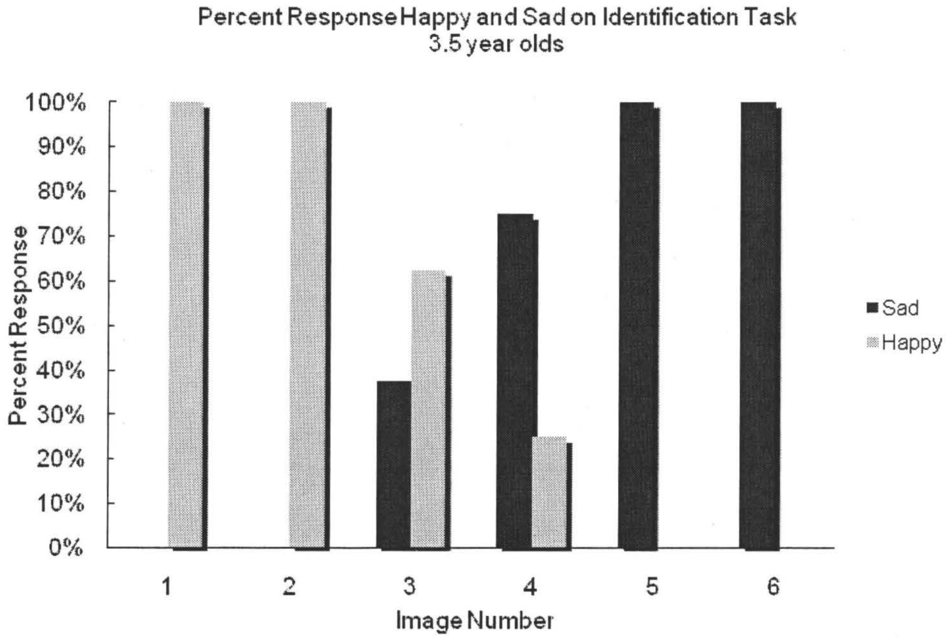


Figure 3
A)


Percent Response Happy and Sad on Identification Task
3.5 year olds
Percent Response
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
Image Number
Sad
Happy

B)

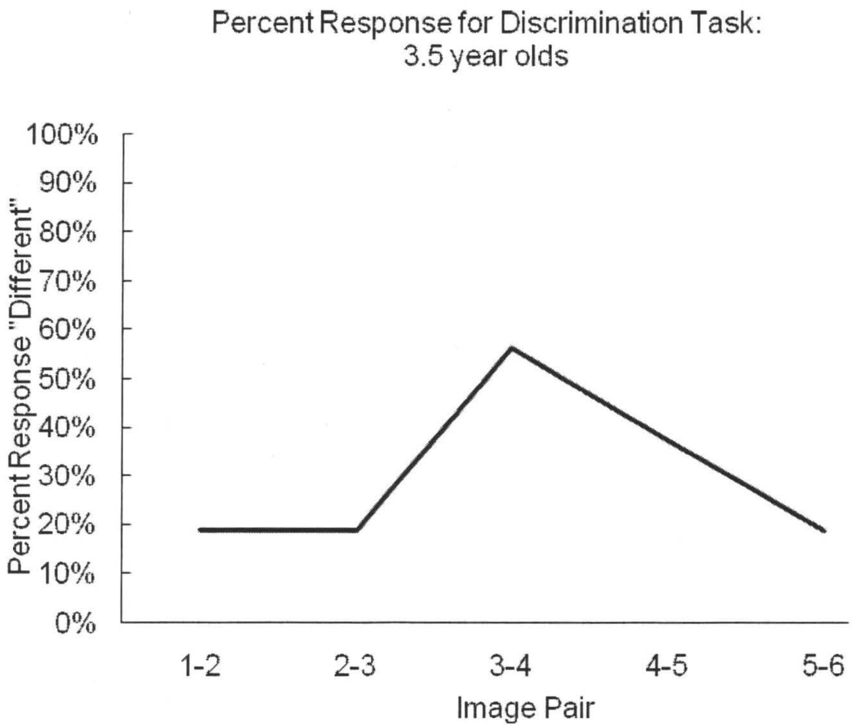
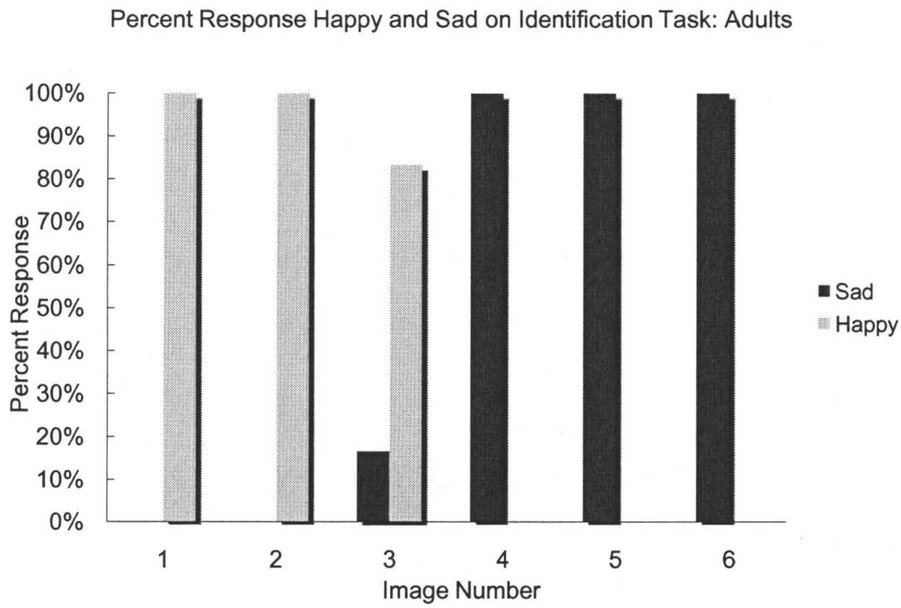
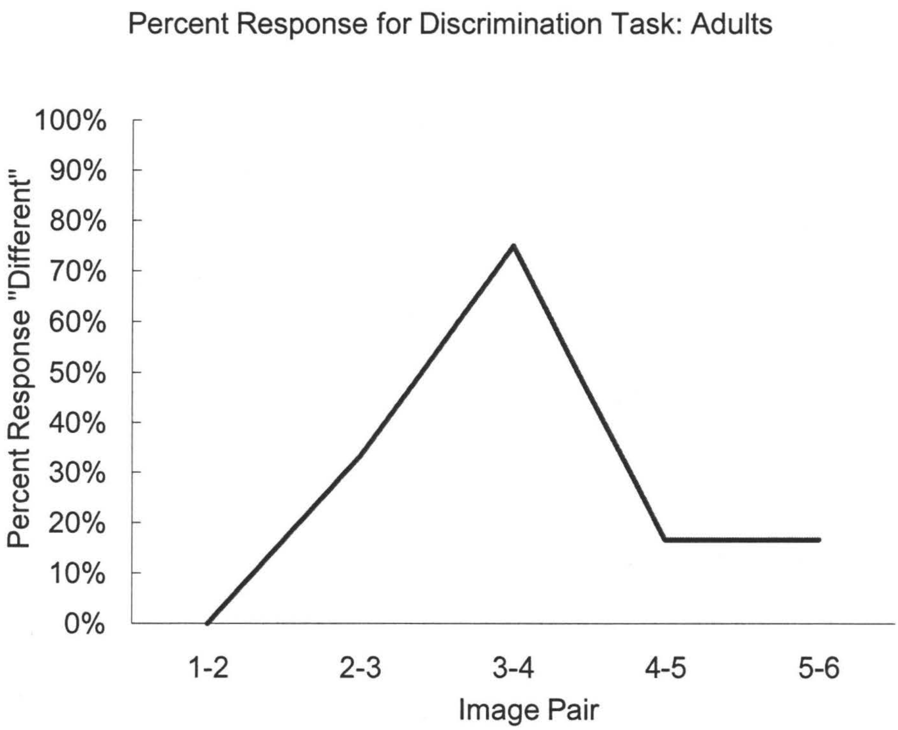

Percent Response for Discrimination Task:
3.5 year olds
Percent Response "Different"
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1-2
2-3
3-4
4-5
5-6
Image Pair

Figure 4
A)


Percent Response Happy and Sad on Identification Task: Adults
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Response
Sad
Happy
1
2
3
4
5
6
Image Number

B)


Percent Response for Discrimination Task: Adults
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Response "Different"
1-2
2-3
3-4
4-5
5-6
Image Pair

CHAPTER 5

MAPPING EMOTION CATEGORY BOUNDARIES USING A VISUAL EXPECTATION PARADIGM

5.1 Preamble

Investigations into categorical perception have traditionally relied upon explicit measures such as verbal response or keypresses. These methods have led to clear findings: emotional facial expressions are perceived categorically (e.g., Etcoff & Magee, 1992). It is within this framework (testing categorical perception of emotional facial expressions) that I chose to test my new paradigm to determine if it can be used interchangeably with traditional keypress designs to elicit category boundary information. In some testing situations and with some special populations an explicit response is undesirable or difficult to obtain. In my method I trained individuals to associate a category exemplar to an eye movement response. After this association is trained ambiguous stimuli are presented and eye direction is recorded, providing information on the categorizations that individuals are making without requiring them to explicitly respond.

This new methodology has great potential for studying some of the areas left unexplored in this dissertation. It could be used in the study of development (see Chapter 4) to extend the findings beyond the currently tested age range, opening up the possibility of testing non-verbal and verbal populations with the same methods. It could also be used to explore individual differences in more detail (see Chapter 2). Bannerman, Milders, and Sahraie (2009) compared saccadic versus manual reaction times and found that saccades are faster when discriminating emotional face stimuli from neutral compared to the same discrimination done using a manual response. This difference was apparent only when presentation time of the stimuli was short. When presentation time was lengthened both saccades and manual reaction time showed facilitation for emotional faces. This study suggests that saccades or eye movements may be a more sensitive measure and therefore are an appropriate venue for investigating the individual difference findings further.

The advantage of this paradigm is not limited to obtaining category boundary information from typical adults, but in applying the method to other areas where an explicit response cannot be obtained. The paradigm could be used with special populations whose verbal abilities can be poor, such as individuals with autism. In addition there are certain experimental setups that require the participant to make limited movements, such as studies using functional magnetic resonance imaging (fMRI) or event-related potential (ERP) measurements. Finally it offers a powerful way to compare behavioral responses using the same task. This could be used to compare across age groups with different verbal abilities or possibly compare across species.

To determine whether a non-verbal response paradigm is feasible in the study of categorical perception of emotional facial expressions I test a new paradigm that relies on an implicit response, eye direction. Participants were trained to expect a target stimulus on a particular side of the monitor, predicted by an emotional expression on a face image. An eye tracker then recorded eye movements of participants as they viewed novel intermediate facial expression stimuli. Anticipatory eye movement was taken as evidence of categorization. Results from two experiments suggest that this implicit method can be used to determine category boundaries, and that the boundaries found with this method are similar to those found using the keypress response, at least in adults.

5.2 Abstract

Past research showing categorical perception of emotional facial expressions has relied on identification and discrimination tasks that require an explicit response via labeling or a keypress. Here we report a new paradigm for investigating the category boundary of a continuum of morphed emotional facial expressions that instead relies on an implicit response, eye direction. Participants were trained to expect a target stimulus on a particular side of the monitor, predicted by an emotional expression on a face image. An eye tracker then recorded eye movements of participants as they viewed novel intermediate facial expression stimuli. Anticipatory eye movement was taken as evidence of categorization. Results from two experiments suggest that this implicit method can be used to determine category boundaries, and that the boundaries found with this method in adults are similar to those found using the keypress response.

5.3 Introduction

Categorical perception is the perception of discrete categories given stimuli that vary continuously on a given physical dimension. Categorical perception allows perceptual systems to translate real-world stimuli into useful information. It is an efficient strategy for organizing incoming stimuli into meaningful, but limited, pieces of information (Harnad, 1987). It has been demonstrated in several domains of perception including speech sounds (Eimas, 1963; Liberman, Harris, Hoffman, & Griffith, 1957), color (Bornstein & Korda, 1984), and emotional facial expressions (Calder, Young, Perrett, Etcoff, & Rowland, 1996; Etcoff & Magee, 1992), for example. Experimentally, when the perceptual response to a stimulus differs from that which would be predicted based on the physical characteristics of the stimulus, categorical perception is said to occur. Specifically, for stimuli that are perceived categorically there is greater sensitivity for between-category discriminations than there is for within-category discriminations as well as more ambiguity when asked to categorize stimuli that occur near the boundary (Harnad, 1987; Repp, 1984).

A procedure used by Bornstein and Korda (1984) for testing categorical perception of color is typical of categorical perception experiments. The first of two tasks is termed an *identification task*, because it involves the participant identifying a stimulus and labeling it. In a typical identification task participants are asked to name (or identify by pressing pre-identified buttons on a keyboard) the categories from which stimuli are drawn. These stimuli come from a continuum that ranges from one category exemplar to another and are created to be physically equidistant from one another.

Results from the identification task are plotted as percent identified with one of two labels for each of the stimuli across incremental physical changes in the stimulus. If perception is categorical, this plot will be “s-shaped” with responses consistently indicating one category or another toward the tails with a steep change in response, around the location of the category boundary (Harnad, 1987; Repp, 1984; Studdert-Kennedy, Liberman, Harris, & Cooper, 1970). The category boundary is the point on the curve where the slope is maximal and corresponds to the point where participants do not consistently respond with one label or the other. This point, called the 50% identification point, is used in conjunction with the discrimination task (described below) to demonstrate categorical perception (Repp, 1984).

In order to infer categorical perception, a second task is used in conjunction with the identification task. In this task, termed the *discrimination task*, stimuli from the range previously tested with the identification task are paired and the participant’s accuracy at discriminating pairs is tested using either a matching or same/different task (Calder et al., 1996; Harnad, 1987; Repp, 1984). Accuracy scores, an index of discriminability, are compared with reference to performance on the identification task. If the stimuli are perceived categorically, there should be a peak in performance where the pair of stimuli spans the category boundary. When the peak in accuracy and the 50%

identification point occur at the same location on the physical continuum, this is taken as sufficient evidence to conclude that the stimuli are perceived categorically (Repp, 1984).

Categorical Perception and Emotional Facial Expressions

Categorical perception of emotional facial expressions was first demonstrated by Etcoff and Magee (1992) who found that a continuum of line drawings between two basic emotions (e.g. happy and sad) were perceived categorically on the basis of identification and discrimination tasks. Other authors (Calder et al., 1996; de Gelder, Teunisse, & Benson, 1997; Teunisse & de Gelder, 2001; Young et al., 1997) followed this study with an examination of morphed photographic images of facial expressions. They also concluded that emotional facial expressions are perceived categorically and that performance on the discrimination task can be predicted by identification task performance.

Recent studies have investigated the time course of categorical perception for emotional facial expressions. In two experiments Suzuki, Shibui, & Shigemasu (2007) found that slopes were lower when the face presentation was brief. In addition, discrimination performance was worse when faces were presented at shorter intervals. These results suggest that categorization occurs at later stages of processing and may involve higher cognitive systems. Alternatively, Campenella, Quinet, Bruyer, Crommelinck, & Guerit (2002) used event-related potentials to determine the temporal course of categorization and found psychophysiological modulation earlier than previous studies have reported when directly comparing between and within category face images.

Our goal was to develop a non-verbal and implicit method to study the category boundary. Previous methods, as described above, have relied on a verbal response, a button press or other response requiring explicit awareness. These responses are the result of a deliberate decision making process. We were interested in categories at their most automatic, with as little explicit decision-making as possible. We were also interested in whether category boundaries obtained in this way are the same as those obtained with the previous methods (namely, keypress identification). One benefit of developing this methodology is that it will potentially allow for comparison with non-verbal populations, such as preverbal infants, learning disabled adults, or even non-human animals. It may also be useful in situations where movement is undesirable, such as when fMRI is used and participants are in a scanner. To test this we developed a new paradigm for testing category boundaries with visually presented stimuli. This paradigm, the visual expectation paradigm, uses anticipatory eye movements to obtain category judgments from participants and requires no verbal response. We trained participants to look to the left or right side of the computer monitor in expectation of a visually presented stimulus, the target stimulus. After training using unambiguous images we presented participants with ambiguous images from a morphed continuum of emotional facial expressions and recorded eye direction with an eye tracker.

5.4 Experiment 1

Experiment 1 was designed to determine if we could elicit category boundary information from participants using the visual expectation paradigm and an eye tracker to record responses. We based our procedure on that of Haith, Hazan, and Goodman (1988) and McMurray and Aslin (2004) but while they tested infants, we tested adult participants. Haith et al. found that infants made eye movements to an expected target location (they anticipated its location) and they had faster eye movements to target location once it appeared (their eye movements were facilitated) in an alternating sequence. Infants used the regularity in an alternating pattern to determine where the next eye movement should be directed. McMurray and Aslin used this information to test category boundaries in infants. In their procedure an object moved behind a visual occluder and reappeared toward the left or the right of that occluder, its position determined by category membership. After this predictable trajectory was trained novel combinations of shape/color objects were tested to determine perceived category membership based on visual response (eye movement left or right). Using eye direction alone McMurray and Aslin were able to obtain category information in a nonverbal manner. Our procedure closely resembles that of McMurray and Aslin and was presumed to reveal expectations of location. Our procedure differed from McMurray and Aslin in that we eliminated the occluder and face images were shown in the center of the screen; the emotion on the face predicted the appearance of a visually presented object on either the left or right hand side, and we tested adult participants.

Method

Participants.

Twenty-three participants (mean age = 19.14 years, *SD* = 1.36, 18 female, 5 male) from the McMaster University undergraduate psychology participant pool were included in this study. All participants were given partial course credit for participating. All participants had normal or corrected-to-normal vision with contacts only. Participants requiring glasses were excluded from the study due to difficulty obtaining data from them using our eye tracker. Two additional participants were excluded from all data analysis because they failed to reach our predetermined criterion during the training phase of the experiment.

Stimuli.

The stimuli in this experiment were created by modifying images from Ekman and Friesen's (1976) *Pictures of Facial Affect* set. Images of one individual, "C" from this picture set were chosen and morphed to create a continuum of emotional facial expressions. We created a happy to sad continuum.

Morpheus v1.85 software was used to create the continuum. The resulting continuum included 9 intermediate images and 2 endpoint (original) photographs for a total of 11 images. The original Ekman and Friesen (1976) images were altered using Adobe Photoshop 7.0 to remove identifying tags and to make all images consistent in brightness. The continuum used in these experiments can be seen in Figure 1.

(Figure 1 about here)

The images were split into two groups, "training" and "test". The six unambiguous extreme images were used during training, as exemplars of their category (3 happy or 3 sad). They corresponded to the images on the ends of the continuum (images 1-3 and 9-11). Previous research (e.g. Etcoff & Magee, 1992) suggests that these endpoint images are unlikely to be part of the category boundary as they are consistently categorized as happy or sad. Test stimuli were the five middle images, images 4-8 of the 11 image continuum.

Procedure.

Participants were seated such that the distance between the monitor and their eyes was 57 cm and was maintained using a chinrest. Stimuli were presented on a NEC MultiSync FE990 flat CRT monitor 36.5 by 27.5 cm. Stimuli were displayed using E-Prime software version 1.0. Eye direction data were obtained using an ASL (Applied Science Laboratories) remote mounted model 6000 – 504 eye tracker which uses a CCD camera positioned below the monitor displaying the experimental stimuli to record a pupil and corneal reflection and has a sampling rate of 60 Hz.

Participants were told that they would see a series of images on the computer screen and that they should look at each of the images. They were told that they would see images of faces presented centrally followed by images of objects on the left or right side of the screen. The face images subtended 11.5° x 16°. Participants were instructed to look at the objects and try to remember them for a later memory test. The memory test was used to give the participants incentive to look at the objects. While infants will preferentially view novel visual displays our pilot testing suggested adults did not find these appearances rewarding enough to look at them spontaneously. They were told that each face would have an emotion and that the emotion would predict the location where an object would appear. Objects were scaled to fit in a square area at the edge of the screen occupying a 5 x 4 cm area.

The experiment started with 24 training trials that were designed to elicit looking to the left or right of the screen based on the emotion presented. Training trials started with the presentation of a fixation cross in the center of the screen for 250 ms. This was followed by a blank screen for 500 ms. Then a training image (one of 6) was presented for 2000 ms. This was followed by another blank screen, the critical interstimulus interval (ISI), for 1000 ms during which participants could make anticipatory eye movements towards one side of the screen or the other. Finally, the target stimulus was presented at 15° to the left or right side of the screen from center for 250 ms. The side of the screen the participants were trained to look towards for each emotion was counterbalanced: half of the participants were trained to look to the right when happy images were presented and to the left when sad were presented, half were trained to look to the left when happy images were presented and to the right when sad were presented.

Following these training trials, 10 test trials were presented. These trials were identical to the training trials except that the face images were the middle five face images from the continuum, the more ambiguous images, and that the target stimulus was not presented for these trials. Instead of a target stimulus the critical ISI blank screen was lengthened to 1000 ms such that all trials took the same amount of time, regardless of whether they were training or test. The target stimulus was removed from the test trials in order to eliminate the possibility of retraining the participant to look to the left or right based on the target stimulus outcome paired with the ambiguous images. Twelve trials identical to the training trials were presented at random intervals during the test trial phase to reduce extinction, ensuring that participants continued to look to the side of the screen where they expected the target stimulus to appear. Participants were not aware that there were training and test sections to the experiment as the sections were presented consecutively (see Figure 2 for trial sequence). The experiment took approximately 10 minutes to complete. Following the experiment participants were asked to circle from a list of common objects the ones that were seen during the experiment in order to maintain the illusion that the purpose of the study was a memory study.

(Figure 2 about here)

Data from the eye tracker were analyzed using ILAB software (Gitelman, 2002). Participants were required to meet a criterion of six consecutively correct eye movements during the critical ISI during training before the target stimulus was presented, or their data were excluded. Two participants were excluded using this criterion. Eye movement data were analyzed using visual inspection of scan paths. An eye movement was considered "correct" if the scan path of the eye traveled outside the area covered by the face image (5.75° from center toward the left or right edge of the monitor) while the face image was presented on the screen or during the blank screen immediately following the face image, the critical ISI. Only the first saccade was analyzed for direction (right, left, or centered). Eye movements subsequent to this saccade were not analyzed as they were not thought to reflect the initial reaction to the face images that we were interested in.

Results and Discussion Experiment 1

Eye movements on the test trials were analyzed for direction of eye gaze during the critical ISI. In order for a response to be classified as either "happy" or "sad" the participant was required to make an eye movement toward the trained side of the screen in the first 750 ms of the post-ISI blank screen (that is, prior to the time the target stimulus would have been presented if it were a training trial). Rather than using a criterion of whether or not the eye direction was toward the left or right side of the screen we used the more stringent criterion that eye gaze must have left the area covered by the predicting face image in order to be classified as a response of either looking left or right: the participant was required to make an eye movement that was outside of the area that had been occupied by the face image, else the trial was classified as "no response" because participants could have been looking at a point on the face and not moved when it disappeared.

Results for each of the 5 middle "ambiguous" images are shown in Figure 3. The bars represent the proportion of trials for each image for which there was "no response", with error bars indicating the standard error for each percentage. The curve created by the "happy" and "sad" responses shows the characteristic "s-shape" of categorical perception. The curve has slightly lower slope than a curve obtained in response to the same stimuli using keypress identification (see Etcoff & Magee, 1992). A pattern seems to be emerging from the "no responses" provided in Figure 3: there are more "no response" trials when participants see images occurring in the middle of the test image continuum, for example images 5 and 6 evoked more "no response" trials than images 4, 7 and 8. These "no response" results are inconclusive because there is a high rate of not responding overall (*mean percent "no response"* = 37.18, *sd* = 6.67) where just over one-third of trials ended without anticipatory eye movements. Further, the rate of "no response" was high and similar for images 5 and 6 of the continuum (43.50% and 44.55% respectively) while for image 5 responses that were recorded were mostly categorized as happy and not an ambiguous mix like those recorded for image 6.

(Figure 3 about here)

Finally, we performed a trend analysis to test if the eye movement response depended on test image. A linear contrast was performed and was significant, $p > .05$, suggesting that the slope of the line increases with the morphing of the face image. Because we were unconvinced that a linear function clearly represented our data we further performed an orthogonal contrast where the ideal pattern for categorical identification was used in the contrast coefficients (the first 5 images labeled -1, the middle image labeled 0, and the last 5 images labeled 1). This contrast was also significant, $p < .05$, suggesting that identification does not depend exclusively on the physical properties of the images. While our data do not perfectly match the "s-shaped" curve obtained using keypress methods it is likely that discrepancies between these two curves are due to methodological differences rather than perceptual differences: the keypress identification task is a 2-alternative forced-choice task while the visual expectation task is essentially a 3-alternative forced-choice (looking left, looking right, or looking center). The pattern of "no responses" can be interpreted similarly to existing reaction time data. Just as reaction times are significantly longer for images in the middle of the continuum (nearest the category boundary) (Bornstein & Korda, 1984), the middle face images are more ambiguous, leading to fewer definitive eye movements. Our next experiment aimed to elucidate this relationship.

A visual expectation paradigm can be used to extract category boundary information from participants. This category boundary information appears to be similar to that obtained using the traditional methodology, such as the keypress response. This suggests that the visual expectation paradigm is effective for measuring the same perceptual processes that are measured by keypress response.

5.5 Experiment 2A

Experiment 2a was conducted as a follow-up to experiment 1 in order to improve the new method. Our goal was to reduce the number of trials for which participants did not make a decisive eye movement, thus preventing us from assigning a label to the image. To that end, we increased the motivation to look at the target stimulus by presenting participants with a more challenging task (watching sequences of letters to form words, for example "girl" or "apple", instead of viewing pictures as the target stimulus). We also decreased the presentation time for the stimuli; results from experiment 1 suggested presentation times were excessive and participants made reliable anticipatory eye movements quickly if at all. Finally, we presented the target stimulus (this time a letter) after all trial types, training and test, because spontaneous feedback from experiment 1 suggested participants were confused about the task requirements when a target stimulus did not appear. In addition to these changes to the visual expectation paradigm we included a comparison group of individuals performing the task using keypress response.

Method

Participants.

Fifteen participants (*mean age* = 20 years, *SD* = 4.94, 15 female) from the McMaster University undergraduate psychology participant pool were given partial course credit for participating in the study. All participants had normal vision or vision that was corrected-to-normal with contacts only. As before, participants requiring glasses were excluded from the study due to difficulty obtaining data from our eye tracker.

Stimuli.

The test stimuli for this experiment were the same images used in experiment 1. Instead of pictures of everyday objects serving as the target stimulus, letters of the alphabet were presented in their place. These letters spelled out words of everyday objects (from 3 to 5 letters long) when attended to sequentially (one letter per trial). The letters were presented right or left justified on the screen (at 15° left or right from center) in courier new font, size 18.

Procedure.

The procedure was similar to that of experiment 1 with these differences: first, the experiment started with eight practice trials. Because attending to letters presented quickly in sequence was a more difficult task than passively viewing small objects we wanted to give participants a chance to become familiar with the task. During practice trials, instead of looking at faces, participants saw squares in the center of the screen that were either blue or red. The color of the square predicted the side of the screen that letters would appear. Each practice trial began with a fixation cross presented at the center of the screen for 250 ms. The predicting colored square was then presented, again in the center of the screen for 1000 ms. A blank screen followed for 500 ms and finally a letter was presented on either the left or right side of the screen depending on what had been predicted by the colored square. Participants were asked to name the words the sequentially attended letters made up in order to assess whether they understood the task.

After the practice trials the training and test trials were presented. Participants were told they would be doing a similar task but this time the letter on the side of the screen would be predicted by the emotion showing on a face image. The first 24 trials were training trials and included only the three images that came from each end of the continuum. These six images were presented in random order and the corresponding letters were presented on the left or right of the screen. For half of the participants the happy images were followed by letters on the left and for the remaining participants happy images were followed by letters on the right, with each group receiving the opposite pattern for sad images (sad images on the right and left respectively). The trials again began with a fixation cross presented in the center of the screen for 250 ms. The participant then saw a face image for 500 ms. They then saw a blank screen, the critical interstimulus interval for 500 ms during which eye direction data were collected. Finally, the letter appeared for 500 ms on the right or left hand side of the screen. The test trials were presented immediately after the training trials such that the participant was not aware of the nature of the two trial types (see figure 4 for trial sequence). The test trials (10 total) differed from the training trials in that the previously unseen middle emotional images from the continuum were shown and unlike experiment 1, the letters that were being identified were presented on both sides of the screen. As in experiment 1, the face images on the test trials were those from the middle of the continuum, the 5 most ambiguous morphs where we expected to find the category boundary.

The target letters were presented on both sides of the screen rather than just the left or right. Because we were interested in participant's eye movement response we did not want to influence them to look one direction over another by presenting the letter on just left or right. In addition, we didn't want the response to extinguish because they no longer had a task to do if we eliminated the presentation of a letter at all. Mixed within these test trials were 12 more training trials identical to the original training trials presented in a randomized order to maintain the eye movements.

(Figure 4 about here)

As before, participants' data were again analyzed using ILAB (Gitelman, 2002) software. Participants had to reach a criterion of anticipatory eye movements toward the correct side of the screen at least six consecutive times during training. No participants were excluded from experiment 2a.

5.6 Experiment 2B

Experiment 2b was run as a follow-up to experiment 2a using a traditional keypress design. In this control condition we presented the exact same face images used in both Experiments 1 and 2 but presented them in the context of a traditional keypress identification experiment. The procedure (face presentation time, etc…) was kept as close to the procedure of Experiment 2 for comparison purposes, but it required participants to make an explicit keypress response. The explicit response data from this condition are presented alongside the Experiment 2a data to illustrate the similarities in the paradigms in obtaining category boundary information.

Method

Participants.

Ten participants (*mean age* = 21.2 years, *SD* = 2.6, 7 female) were included in a control keypress task and were given partial course credit for participating in the study. All participants had normal vision or vision that was corrected-to-normal.

Stimuli.

The test stimuli for this experiment were the same images used in experiment 1 and 2a. In contrast to experiment 1 and 2a there was no visual stimulus or letter presented.

Procedure.

The keypress comparison task was similar to the visual expectation paradigm but eye movements were not recorded and participants were explicitly asked to determine if the emotion on the face looked "happy" or "sad". Participants did not complete a practice phase because the instructions were easily understood. Instead, participants were told they would be viewing a series of briefly presented faces and that they should decide if the face was "happy" or "sad" by pressing either "f" or "j" on the keyboard. The structure of the trials was similar to that of the visual expectation paradigm in experiment 2a. Participants were presented with 24 training trials in which only the six unambiguous face images were shown in random order to be categorized. Immediately after these training trials the test trials were presented such that the participant did not know the two parts of the experiment. The test trials were the 5 middle ambiguous images from the continuum, each presented twice (10 total test trials). Mixed within these test trials were 12 more training trials identical to the original training trials presented in a randomized order to keep the procedure as close to the original visual expectation procedure as possible. As in the visual expectation procedure, participants saw a fixation cross for 250 ms and then the face image appeared for 500 ms. In contrast to the previous procedure the participant then could make their response at any time during a blank screen that followed the face image. The length of time of the blank screen was determined by how long it took the participant to make a response. No visual stimulus or letter was presented in this condition.

Results and Discussion Experiment 2A & B

Criteria for categorizing an eye movement as "happy" or "sad" were the same as were used in experiment 1. Results for each of the middle ambiguous images are shown in Figure 5. The bars in the graph represent cases for each image of "no response". The curve created by the "happy" and "sad" responses shows the characteristic "s-shape" of categorical perception. Keypress response is provided in light gray for comparison.

(Figure 5 about here)

Again, it appears that a pattern emerged from the "no responses" as seen in the bars in Figure 5, again with standard error shown. The pattern is similar to that obtained using reaction time data. When given a choice of not responding participants are less likely to respond when they are not sure which emotion is being depicted by the emotion in the face. This can be seen in the increased "no response" responses to the middle, most ambiguous, test stimuli.

Finally, we performed a trend analysis to test if the eye movement response depended on test image. A linear contrast was performed and was significant, $p > .05$, suggesting that the slope of the line increases with the morphing of the face image. Because we were unconvinced that a linear function clearly represented our data we further performed an orthogonal contrast where the ideal pattern for categorical identification was used in the contrast coefficients (the first 5 images labeled -1, the middle image labeled 0, and the last 5 images labeled 1). This contrast was also significant, $p < .05$, suggesting that identification does not depend exclusively on the physical properties of the images.

Results from experiment 2 suggest that category boundary information can be reliably that obtained using the visual expectation paradigm. In addition, participants' failure to respond to certain images over others suggests the location of the category boundary. In this case image 6 was the most ambiguous (with 36.7% of individuals responding "happy" and 43.3% of individuals responding "sad"). The number of "no responses" was also highest for this 6^{th} image of the continuum, with 20% of trials ending without an anticipatory eye movement.

5.7 Overall Discussion

Using the visual expectation paradigm, we were able to identify adults' category boundary for emotional facial expressions solely based on an implicit response: eye movements. This is the first demonstration, to our knowledge, of categorical perception of facial expressions based on an implicit response. The elimination of the need for a verbal explicit response leaves this methodology open for use with varying populations. Its applications could be far ranging, from individuals who are unable to provide a verbal response or follow detailed instructions (i.e. infants or individuals with autism or learning disabilities) to applications in which a verbal or motor response is undesirable (i.e. in an fMRI where movements must be limited) or possibly for cross species comparisons. In addition, the visual expectation paradigm can be adapted to investigations of categorical perception in other domains. Any continuous stimuli that are presented visually could be potentially investigated using this methodology.

In addition, we were able to replicate the findings of previous studies on categorical perception of emotional facial expressions other authors (Calder et al., 1996; de Gelder et al., 1997; Etcoff & Magee, 1992; Young et al., 1997) have found with the typical keypress identification task. Our own control condition (experiment 2b) found a similar pattern of responses for the ambiguous stimuli when they were presented using the visual expectation paradigm and when they were presented in a more traditional keypress experimental design. This suggests that the task we have developed is a valid task for the identification information that we are seeking.

One consequence of using the visual expectation paradigm was that the change in task type necessarily changes the possible responses. In the traditional keypress identification task participants have a 2-alternative-forced-choice. In our task participants could look to the left or right of the screen or their eyes could stay centered, therefore the choice between 2 exemplars was not forced. In the keypress identification task participants almost always make a response (Etcoff & Magee, 1992; Young et al., 1997) even if that response is random. In our task, many times (up to 44.55% for image 6 in experiment 1) participants made no response to the ambiguous images presented. In experiment 2 we attempted to reduce this by making the task more engaging and difficult to increase motivation to look to one side of the screen. We were successful in reducing the number of times that participants did not make responses (from an average of 37.18% no response in experiment 1 to an average of 11.98% no response in experiment 2 over the five middle test images), but were unable to completely remove it. Despite this problem, the pattern of "no responses" is interesting on its own, suggesting that the middle images of the continuum are the most ambiguous and difficult to classify. We chose not to simply split the screen in half and classify eye direction as either to the left or to the right because our categorization stimulus was large and the eyes could potentially have been moving over a large area of the middle of the screen and still be looking at the face. For this reason we considered the 3-alternative-forced-choice analysis to be a more stringent test of the paradigm.

Only one individual's images were used in this study and participants had only 10 opportunities to respond with their eye direction to which side of the screen they expected to see the target stimulus. Only one individual was used in order to reduce the task demands for the participants. We do not know if training on emotional face images of one individual will transfer to being able to categorize ambiguous expression images of another individual, however recent studies suggest some overlap in identity and expression processing (Ellamil, Susskin, & Anderson, 2008). We therefore chose to use one individual to provide all of the images for this first test of a new methodology in order to minimize interference from unknown and untested variables. Future studies could include a broader range of identities and larger number of test trials to determine the limits of this methodology.

It is likely that participants knew our goal was to determine how they were categorizing emotional face images, particularly because participants were told that the emotion on the face predicted the side of the screen where the target stimulus would appear. This instruction was included because pilot testing suggested participants did not find target stimuli rewarding enough to look towards spontaneously. It is unlikely that participants were able to deduce the nature of our predictions about the location of the category boundary and the phenomenon of categorical perception for these faces. The fact that the faces were morphed was not disclosed to participants and they only had the brief training phase to make guesses about the aims of the study. Therefore, it is unlikely that participants could guess the aim of the study and use this information to influence the results. Categorical perception of emotional facial expressions is a robust phenomenon for the basic expressions investigated here.

Another disadvantage of our method is that discrimination performance, comparing the accuracy of discriminating pairs of adjacent stimuli, has not been evaluated. In order to infer categorical perception the accepted standard is to compare identification performance to discrimination performance as described above. In this case we have tested only identification performance, and while it is comparable to identification performance using a keypress identification that has been compared to discrimination performance (Harnad, 1987; Repp, 1984), we cannot conclude with certainty from the present results that performance is categorical, we can only identify the location of the category boundary in cases where previous research suggests perception is categorical. In this case we were interested in testing whether this methodology could be used to investigate the category boundary and not used as a strong test of categorical perception of emotional facial expressions. A more rigorous test of the methodology would be to develop a discrimination task that relies on eye movements rather than verbal or keypress responses and to compare the data from these tasks. This is a direction that we will explore in the future.

Recently, Bannerman, Milders, and Sahraie (2009) compared speed of discrimination in a forced-choice paradigm using saccades and manual reaction time. They found that for emotional stimuli reaction time was faster when measuring saccades over manual responses. This suggests that eye movements may indeed prove to be a more sensitive measure of discrimination that could be utilized in future studies of categorical perception.

In addition to the development of a discrimination task using the visual expectation paradigm we intend to test this paradigm using other populations. Because a verbal response is not required for its use, it is a potentially powerful tool for testing atypical populations, such as individuals with autism. In addition it could be adapted for use with children as it has the advantage of being fast and not requiring a verbal response. Future studies could also include the comparison of response to a task that is not expected to result in categorical perception as a control.

The visual expectation paradigm is a powerful new methodology for the study of the category boundary using non-verbal methods. As our investigation with emotional facial expressions shows it can be reliably used to identify category boundary information. It also provides researchers a way to investigate categories and compare those results to those that have been found with more traditional methods.

5.8 References

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5.9 Figures

Figure Captions

Figure 1. Morphed continuum of facial expressions used as stimuli in experiments 1 and 2.

Figure 2. Experiment 1 trial sequence.

Figure 3. Percent response in experiment 1 with images of small objects as the target stimulus. Bars represent "no response" and are shown with standard error.

Figure 4. Experiment 2 trial sequence.

Figure 5. Percent response in experiment 2 using letters as target stimuli. Black lines represent responses recorded using eye movements. Gray lines represent keypress response happy. Broken lines show categorization of unambiguous happy and sad face images, from the three unambiguous face images from each end of the continuum. Bars represent "no response" from the eye movement data, with standard error.

Figure 1

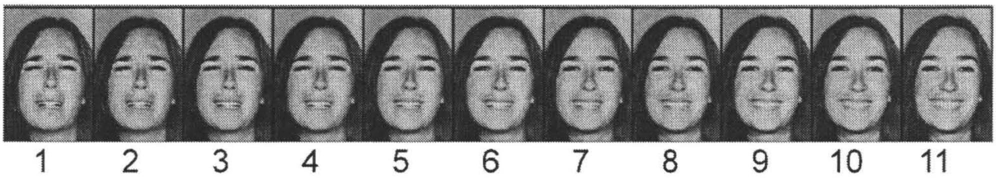


Figure 2

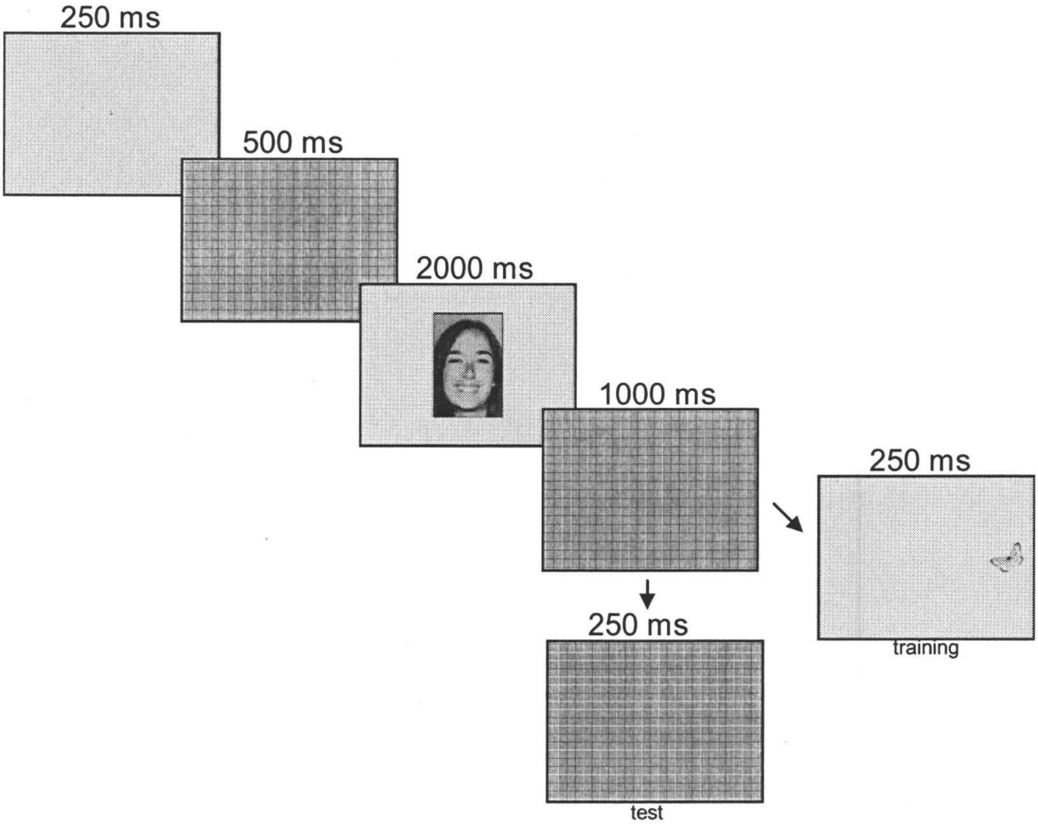


Figure 3

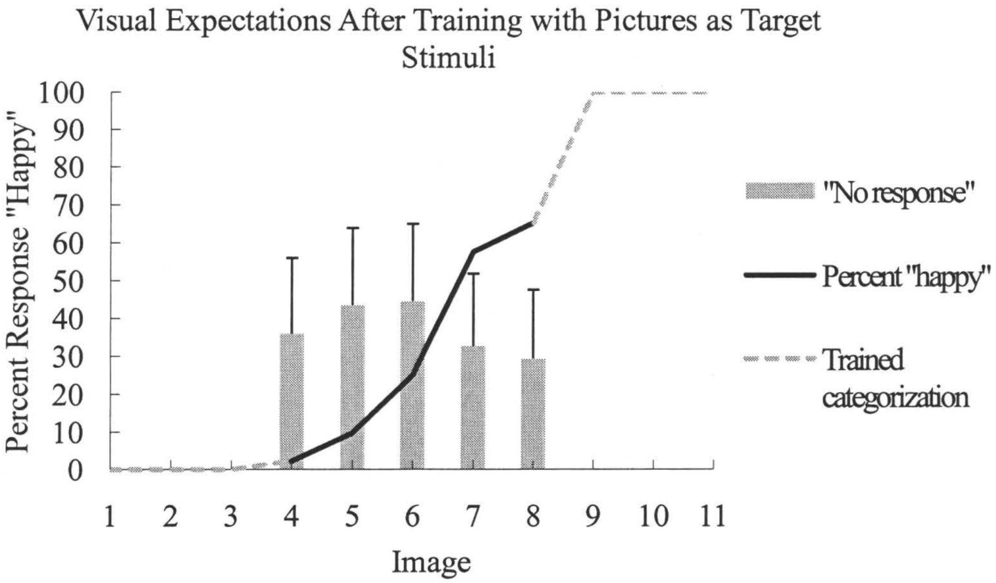

Visual Expectations After Training with Pictures as Target Stimuli
Percent Response "Happy"
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
Image
"No response"
Percent "happy"
Trained categorization

Figure 4

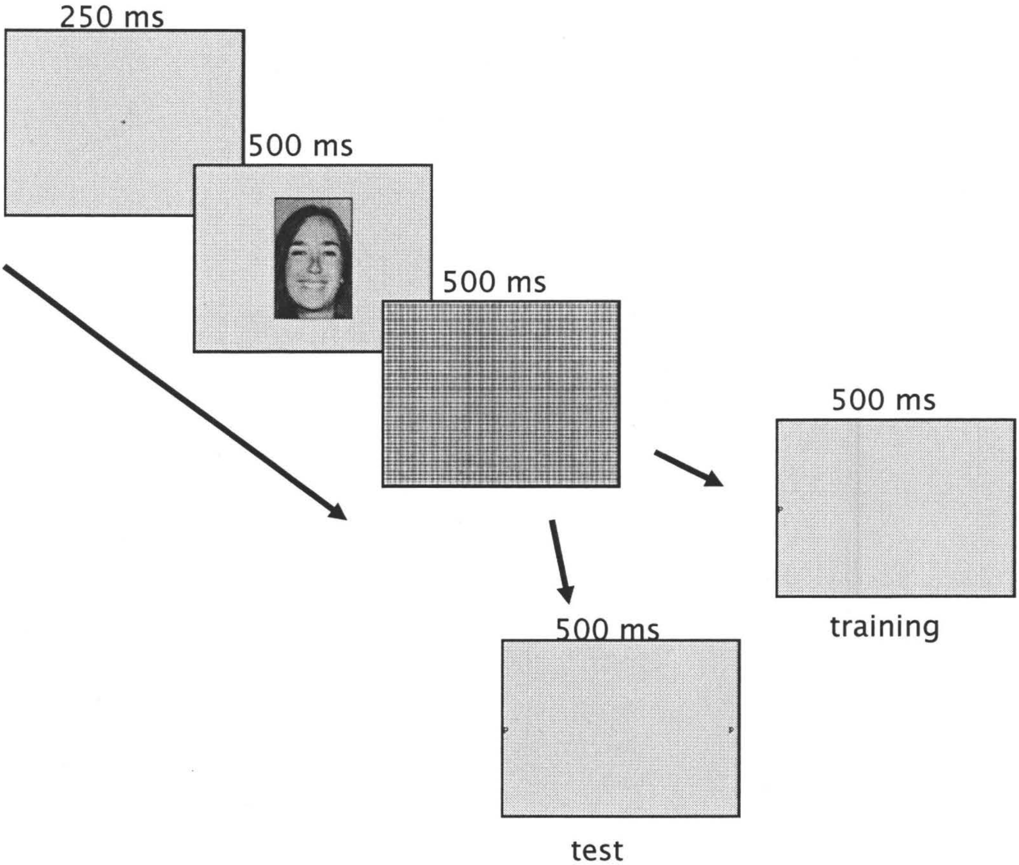
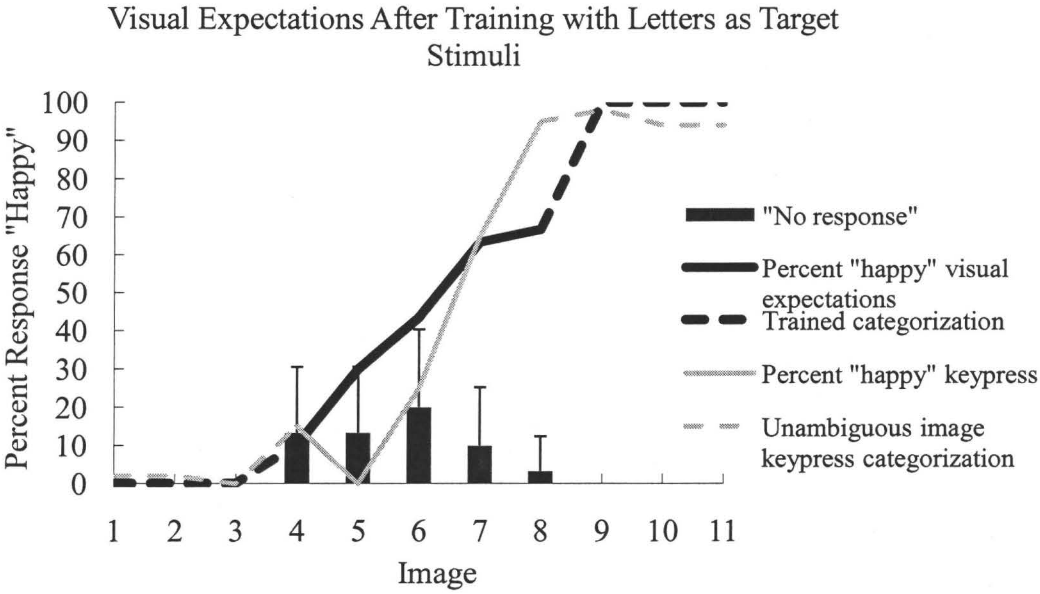


Figure 5


Visual Expectations After Training with Letters as Target Stimuli
Percent Response "Happy"
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11
Image
"No response"
Percent "happy" visual expectations
Trained categorization
Percent "happy" keypress
Unambiguous image keypress categorization

CHAPTER 6

GENERAL DISCUSSION

6.1 Summary of Findings and Contributions

"Categorical perception may not only furnish the building blocks – the elementary units – for higher order categories, but it may also provide a representative model for the categorization process in general." (Harnad, 1987a, pp. 3) Categorization is an important concept in perception because, as suggested by Harnad (1987a), it forms the groundwork for our cognition. Categorization allows for efficient processing; it solves a major problem of perception, defining useful categories of information.

In four empirical chapters this thesis closely investigates several aspects of categorical perception, the perception of qualitative differences between stimuli. These aspects of categorical perception of emotional facial expressions have thus far been overlooked in the literature including individual differences, contextual influences on the perception of surprised faces, categorical perception in preschoolers, and a proposed new methodology using eye direction to studying categorical perception of visually presented stimuli.

6.1.1 Individual Differences

In chapter 2 I examine individual differences in categorical perception for emotional facial expressions. Previous studies have relied on group statistics, but an investigation into how individuals perceive these stimuli is important to rule out effects of using particular stimuli (i.e., a particular model posing an expression) and to determine whether averaging across participants is creating or masking any effects in group data. In this seminal study I show that individual differences occur in the perception of emotional facial expressions. I used a typical categorical perception task (examining identification and discrimination for 4 happy-sad continua) but analyze the data for each participant individually. My two experiments demonstrate that categorical perception of emotional facial expressions is a robust phenomenon with a few consistent performance differences. The category boundary varies depending on the individual perceiving the expression. Category boundaries also tend to be stable over time. I also found differences between continua of emotion displays developed from different models posing for the photographs. In this study one model had a boundary that was shifted a step away from the three other models tested, a shift that could not be explained by the intensity of the expressions that were used to create the morphed continuum. These data suggest categorical perception is a robust phenomenon even at the individual level.

This chapter provides several important contributions to the existing literature on categorical perception of emotional facial expressions. First, it is the first study examining categorical perception of emotional facial expressions from an individual participant basis. This is an important step towards bringing research on categorical perception in this domain closer to the level of other investigations of categorical perception (such as speech perception). Analysis at the individual level tells us how robust the phenomenon is – is it ubiquitous or do a certain number of individuals produce the effect when results are averaged? Critics of the categorical perception literature might suggest that categorical perception can be detected or masked depending on how close the performance of individuals is to one another. This study shows that even though not all individuals perceive expressions the same way there is an underlying pattern of categorical perception for individuals, reflected by discrimination performance that matches identification performance.

6.1.2 Context of Surprise

Chapter 3 is an investigation into the effects of context on categorical perception. While some researchers have found all basic emotions to be perceived categorically others have failed to demonstrate categorical perception of surprised faces. In this chapter I review the evidence for categorical perception of surprised faces and suggest that surprise differs from other basic emotions for two reasons. First, to be surprised one must have a prior belief that is violated. This prior belief is a cognitive component to surprise that other basic emotions do not have, and therefore might influence perception of surprise. Second, surprise can be positive or negative in valence, again, unlike other basic emotions. Depending on the context of the surprised expression its interpretation may change. I examine surprise and its context in a study where participants identified or discriminated images that were drawn from 3 morphed continua: happy-fear, surprise-fear, and happy-surprise. Half were provided with a context for the surprise expressions in the form of a short description of a surprising situation. I found that all groups had typical identification curves, but discrimination performance was better predicted by identification in the context condition for happy-fear and surprise-fear continua, suggesting categorical perception for those stimuli presented with a disambiguating context.

This chapter contributes to the existing literature a close examination of surprised faces. Previously published studies have examined all basic pairings of emotion but none have provided any manipulations that would help explain why surprised faces are not always perceived categorically. By manipulating the context of my surprised expressions I show that context can change categorical perception. The idea of top-down processes influencing perception has been previously established (e.g., Carroll and Russell (1996) found that the context of a situation influences how an expressions is perceived) however no study of categorical perception of emotional facial expressions has shown that this perceptual phenomenon changes. This study takes an important step in extending the current research into a new domain. It further contributes to the finding that threat may be particularly important. Threat detection has been an important and active area of research for other areas of cognition and perception (e.g., Krysko & Rutherford, 2009; Öhman, Flykt, & Esteves, 2001). This finding adds to that literature and supports the argument that human cognition is specialized to detect certain states that are likely to be harmful (Nesse, 1990).

6.1.3 Development of Categorical Perception

In chapter 4 I extend the findings of categorical perception of emotional facial expressions to the developmental literature. I explore categorical perception in 3.5-year-olds by creating a morphed continuum of emotion faces, and testing discrimination and identification performance. In the discrimination task two adjacent images from the continuum were presented and participants indicated whether the two images "felt the same" or "felt different". In the identification task images were presented individually and the participant was asked to label the emotion displayed on the face (i.e., "Does she look happy or sad?"). Results suggest that 3.5-year-olds have the same category boundary as adults. They were more likely to report the image pairs felt "different" at the image pair that crossed the category boundary. These behavioral results suggest that 3.5-year-olds perceive happy and sad emotional facial expressions categorically, as adults do.

This research makes an important contribution to developmental research on categorical perception. Previous studies have provided evidence for categorical perception in young children (e.g., Franklin, Clifford, Williamson, & Davies, 2005) and even infants (Kotsoni, de Haan, & Johnson, 2001). The authors of these studies however have failed to use the currently accepted procedures to meet the definition of categorical perception. In most studies only a discrimination or identification task is used. Without a correspondence between the two tasks, it is unknown if perception is truly categorical for those stimuli. This study provides the first evidence of categorical perception in young children that uses both tasks and compares them to data obtained from adults using the exact same procedure.

6.1.4 Visual Expectation Paradigm

In chapter 5 I report a new paradigm for investigating the category boundary of emotional facial expressions that relies on an implicit response, eye direction, rather than an explicit keypress design. Participants were trained to expect a visual reward on a particular side of the monitor, predicted by an emotional expression on a face image. An eye tracker then recorded eye movements of participants as they viewed novel intermediate facial expression stimuli. Anticipatory eye movement was taken as evidence of categorization. Results from two experiments suggest that this implicit method can be used to determine category boundaries, and that the boundaries found with this method are similar to those found using keypress response.

This chapter contributes a new paradigm for investigating categorical perception of emotional facial expressions. Previous research has relied on participant responses using keypress or verbal responses, while this new methodology relies on eye movements. Eye movement response can be desirable in a number of situations. Pre- or non-verbal populations could be tested allowing comparison across different groups. Some testing procedures, such as fMRI, require that participants make very little movement. Categorization could be studied using this method while brain activation is also being recorded. Not only is this methodology useful for studying categorical perception of emotional facial expressions, but it could be adapted to measure categorization of any visually presented stimuli.

6.2 Limitations

6.2.1 Stimuli

One particular limitation that has the potential to impact all the studies described in this thesis is the use of the Ekman & Friesen (1976) *Pictures of Facial Affect* as stimuli. As discussed in the Introduction, these images were chosen for specific reasons, including the ability to compare the results of other published work using the same faces, the fact that the expressions were made by individuals trained to make the specific movements necessary to produce each expression, and because independent testing gives us ratings on how individuals perceive these expressions. Each of these points has been important for maintaining experimental control and being able to compare the current results with previously published data. A potential problem with testing using only these faces is that the results we have obtained may not be generalizable to other face sets.

The use of morphed stimuli could be a potential problem as well. The technique used to morph images uses interpolation between user defined points to shift one image to the other. A problem with this technique for studying faces is that the intermediate images created from the morphing software are not real face images. While the intermediate images may be easily classified as an emotion, they often are not, in fact, facial expressions that individuals actually do convey.

These facial configurations may not even be possible to make given the musculature of the face. Despite this problem, the fact that intermediate morphs are categorized as an endpoint expression can actually help support a claim of categorical perception. When stimuli are perceived categorically they are perceptually grouped. The fact that artificial faces are readily accepted into pre-existing expression categories is further evidence that the brain organizes incoming information, at least for these expressions, into the meaningful groups it has already established. The alternative for these artificial faces would be to be perceived as aberrant or perhaps "mixed emotions". Studies that have included a free naming identification task suggest this is not the case (e.g., Etcoff & Magee, 1992).

A more naturalistic test of categorical perception of emotional facial expressions would employ faces that move from one expression to another as would happen if the individual really displayed those expressions sequentially. This could be done using actors posing expressions on video and taking the intermediate frames and testing identification and discrimination. The problem with this technique is that the physical changes between each step in the continuum would be uncontrolled. To assess categorical perception, the stimuli used to test it must be in equal physical increments. The morphing technique solves this problem by imposing equally spaced physical increments on face images and allows for precise laboratory controlled presentation of intermediate stimuli.

Another potential problem with using static images of expressions is that we do not know for sure whether individuals are using a particular strategy for making identification and discrimination judgments. As with all of this literature, a finding of categorical perception of emotional facial expressions relies on the assumption that individuals are actually using the emotion in the face to categorize expressions. Using static images has the potential for participants to adopt a particular strategy, unbeknownst to the experimenter. If the stimuli are not prepared carefully, artifacts in the images resulting from the morphing technique might mean that the image has a feature that can be used to identify it and does not reflect the assessment of any emotion information at all. This problem could be partially eliminated by using variable and dynamic face images, such as video sequences under different lighting conditions and viewpoints. The trade-off of using these more naturalistic stimuli is a loss of experimental control. Because categorical perception is a precise perceptual phenomenon, these static images are required.

Finally, my experiments used a limited selection of continua. The finding of categorical perception of emotional facial expressions is well established for most basic expressions. These experiments built on previous work and therefore used only a few continua to investigate these areas. In Chapters 2, 4, and 5 a happy-sad continuum was used to investigate individual differences, categorical perception in development, and to test our new paradigm. In Chapter 3 we tested

3 continua, happy-surprise, happy-fear, and surprise-fear. It is unknown how different continua and models posing the expressions would change our results.

6.2.2 Procedure

In Chapters 2 and 5 I used only a subset of a full continuum for my tests. In both cases I chose to exclude the 3 images from each end of the continuum and use them as training images. Based on previous research it is known that these images are unlikely to be part of a category boundary. The advantage to using more than one image in training is that the participant is exposed to more than one exemplar of a category, such that they will not make subsequent comparisons based on matching it to one particular physical instance. While this is desirable, a methodological issue arose in attempting to locate the category boundary for model EM in Chapter 2. Using only this subset of the full continuum it was difficult to determine the shape of the identification curve due to the limiting boundary imposed on the number of stimuli tested. Despite that limitation, I was able to identify the category boundary and we matched the discrimination peak to that boundary in experiment 2. Other studies (e.g., Calder, Young, Perrett, Etcoff, & Rowland, 1996) have used this particular model and found performance to be categorical.

Laboratory conditions for emotion processing experiments may lack external validity. The way we encounter facial expressions in the real world is not by being presented with them in black and white still images. Expressions have a host of accompanying contexts and information. One advantage of my procedure in Chapter 3 was that I provided a context (in the form of a short story) to participants about the images they were viewing. This ultimately led to changed perception for surprise facial expressions. Because real emotional expressions are accompanied by voice cues, body postures, and situational contexts, it is important to consider the influence of these factors when conducting psychophysical experiments and interpreting results (Lewis, 1993). Chapter 3 in particular suggests that the influence of context is important for perception, particularly when the emotion is ambiguous.

In Chapter 3 I did not find any effect of the valence of the context story. I included stories with different valences to determine if there was something special about fear that was driving this effect. This study did not support this interpretation; a context story that was either happy or fearful changed perception. My happy and fear stories may not have been equated in arousal as the stories were not pre-tested for this. We cannot know for sure if other types of stories might influence categorization. More naturalistic stimuli (perhaps viewing vignettes of surprising situations with actors who will later be displaying the expressions) might alter this finding.

One consequence of using the visual expectation paradigm in Chapter 5 was that the change in task type necessarily changed the possible responses. In the traditional keypress identification task, participants have a 2-alternative-forced-choice. In this task, participants could look to the left or right of the screen or their eyes could stay centered, therefore the choice between 2 exemplars was not forced. In the keypress identification task participants almost always make a response (Etcoff & Magee, 1992; Young et al., 1997) even if that response is random. In this task, participants often made no response to the ambiguous images presented. Despite this problem, the pattern of "no responses" is interesting on its own, suggesting that the middle images of the continuum are the most ambiguous and difficult to classify. It is still difficult to compare the results of this task to those of a traditional keypress design for this reason.

Another limitation of the new paradigm is that discrimination performance has not been evaluated. To infer categorical perception, the accepted standard is to compare identification performance to discrimination performance. In this chapter I have tested only identification performance, and while it is comparable to identification performance using a keypress identification that has been compared to discrimination performance (Harnad, 1987a; Repp, 1984), I cannot conclude with certainty from the present results that performance is categorical. Instead, I can only identify the location of the category boundary and rely on comparing this to cases where previous research suggests perception is categorical.

6.3 Future Directions

The experiments presented in this thesis leave several avenues open for future research. These include extending the current work to include different individuals posing the expressions, testing different emotional expressions, and developing more rigorous tests of the new paradigm, for example.

6.3.1 Individual Differences

One of the goals of Chapter 2 was to investigate the category boundary between emotional facial expressions. My data suggests that the model influences the location of the category boundary. Future studies could systematically vary features of faces (for example, open or closed mouth smiles) to determine if there are other changes in boundary due to these differences in starting stimulus. Another direction that could be explored would be to use other stimulus sets for images of expressions. A stronger test of the current data would be to compare the results to those obtained using color images of faces or perhaps images of dynamic faces (as discussed above, see section 2.2).

6.3.2 Context of Surprise

In my experimental manipulation the valence of the context story did not change the perceptual outcome: perception was categorical for both positive and negative stories. Future directions could explore the types of context information that change categorical perception. Perhaps stories that are more convincing or have greater affective responses associated with them are necessary to change perception. It is also possible that individuals do not need specific contextual information to change their perception—it could be that any additional information provides the impetus to pay more attention to the face images that are being presented. This idea could be investigated by looking at the relationship between attention and categorical perception, a research area that is currently unexplored.

Another area of potential interest would be to explore categorical perception in a naturalistic setting. This could be accomplished by presenting videos of individuals in surprising situations and then testing categorical perception using images taken from those videos. It would be interesting to manipulate how well the participant knew the individuals in the surprising situations. Perhaps making the individuals look more or less like themselves (for example, DeBruine, 2002) or using family and friends as stimuli we would find that categorical perception increased based on importance of the situation and the relationship.

Future studies might also explore fear perception by looking at whether category boundaries shift in response to contextual information suggesting a threat. Several existing studies have found evidence that threatening faces and stimuli are processed more quickly than non-threatening ones (Krysko & Rutherford, 2009; Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001). The current findings are in line with the existing literature on privileged processing of threat, and it is possible perception of other continua of emotional expressions might change when fear or threat is involved.

6.3.3 Development of Categorical Perception

In this chapter I focused on designing a study to look at identification and discrimination performance in preschoolers that used a single continuum, happy-sad. The happy-sad continuum was chosen because young children are most accurate in discriminating those expressions and they are able to provide verbal labels for them. Both of these things were essential for them to complete both identification and discrimination tasks. It would be interesting to test expressions that young children are not as good at discriminating and labeling. Pairings of negative expressions in particular would provide a stronger test of categorical perception in young children.

Further, studies of adult categorical perception typically include a 10 step continuum. I reduced the number of morphs that participants would see to keep the overall number of trials low, keeping the task within the child's attention span. Future studies could include more steps in the continua to get a more precise category boundary location. This could be done by making the tasks more engaging or using a between subjects design such that each participant is not required to complete all of the tasks.

The current research used only one age group: 3.5-year olds. Future studies could include younger and older children to map a developmental trajectory. Similar procedures as those described in Chapter 4 could be used to test other preschoolers and toddlers. A new methodology will need to be developed to test infants that includes both a habituation design for testing discrimination and a visual expectation design (see section 3.4) for testing identification.

6.3.4 Visual Expectation Paradigm

This paradigm should be tested with other populations. Because a verbal response is not required for its use, it is a potentially powerful tool for testing atypical populations, such as individuals with autism. In addition, it can be adapted for use with children or infants as it has the advantage of being fast and not requiring a verbal response. One way it could be adapted would be to use it to obtain identification data from infants. Infants would be trained to look to one side of a monitor or another when they are presented with category exemplars. After this relationship has been trained intermediate images from a continuum would be presented and categorization inferred from the direction of eye movements.

In the two experiments in Chapter 5, only one model's images were used and participants had only 10 opportunities to respond to which side of the screen they expected to see the target stimulus. A single model was used to reduce the task demands for the participants. We do not know if training on emotional face images of one model will transfer to being able to categorize ambiguous expression images of another model, however recent studies suggest some overlap in identity and expression processing (Ellamil, Susskin, & Anderson, 2008). I used one model to provide all of the images for this first test of a new methodology to minimize interference from untested number of uncontrolled variables. Future studies should include a broader range of identities and larger number of test trials to determine the limits of this methodology.

Another disadvantage of this method is that discrimination performance, comparing the accuracy of discriminating pairs of adjacent stimuli, has not been evaluated. To infer categorical perception, the accepted standard is to compare identification performance to discrimination performance as previously described. I was interested in testing whether this methodology could be used to investigate the category boundary and not used as a strong test of categorical perception of emotional facial expressions. A more rigorous test of the methodology would be to develop a discrimination task that relies on eye movements rather than verbal or keypress responses and to compare the data from these tasks.

6.4 Conclusions

In this thesis I have examined categorical perception of emotional facial expressions from a number of different perspectives. In Chapter 2 I found in two experiments that categorical perception of emotional facial expressions is a robust phenomenon with a few consistent performance differences. These differences are worth considering especially when using categorical perception tasks with groups other than typical adults where data may be even more variable. These findings highlight some of the important caveats that categorical perception researchers face, not only in the area of emotional facial expressions, but across domains as well. In Chapter 3 I show that context has an effect on the visual perception of emotional facial expressions. The surprise-fear and happy-fear continua were perceived categorically only in the case where a context story was provided for the surprised face. This is new evidence showing top-down processing changes categorical perception for emotional facial expressions and suggests we need to think about categorical perception more broadly, incorporating and testing other ideas from cognition rather than solely focusing on a psychophysical approach. In Chapter 4 I demonstrate categorical perception for a happy-sad continuum in 3.5-year-olds. This is an important study in development because the current literature is limited by studies that do not compare identification and discrimination performance in these age groups. The experiment in this chapter uses both identification and discrimination tasks and compares the results of 3.5-year-olds to adults who do the exact same task. The results suggest that 3.5-year-olds perceive happy and sad expressions as adults do: categorically. In Chapter 5 I develop a powerful new methodology for the study of the category boundary using non-verbal methods. This investigation with emotional facial expressions shows it can be reliably used to identify category boundary information. It also provides researchers a way to investigate categories and compare those results to those that have been found with more traditional methods, such as keypress designs.

These chapters provide a more in-depth understanding of categorical perception of emotional facial expressions and are a valuable addition to the existing literature on this topic. Research on individual differences is a contribution to the field because it shows that group performance data is an accurate reflection of the processes occurring for the individual. In addition, it brings research on categorical perception of emotional facial expressions a step closer to being as thorough as the research on categorical perception in other domains. The research on context influencing the perception of surprise suggests that research in perception of emotional facial expressions needs to take the broader context of expressions into consideration. It will be important for perception researchers to acknowledge this in future work. A finding of categorical perception in preschoolers confirms the assertion of existing literature that has suggested young children and even infants perceive expressions categorically. This study however, has gone beyond previous research by testing both identification and discrimination as is standard in the field but surprisingly has yet to be done with this age group. Finally, the use of eye tracking methods opens up research on categorization to populations that could not be tested previously. This is not only important for research in the domain of categorical perception, but for other studies of categorization as well. If categorical perception is indeed a building block of all categorization then this thesis provides an additional layer to understanding that process. Perception of emotional facial expressions is an essential part of successful social cognition, and the phenomenon of categorical perception specifically allows individuals to quickly and accurately respond to expressions. The research contained within this thesis is a further step in understanding the processes that allows individuals to be successful in a social environment.

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