THE DEVELOPMENT OF FACE EXPERTISE: THE ROLE OF RACE, DISTINCTIVENESS AND INTENTIONALITY

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Face perception and recognition is an area of much research across infancy, childhood, and adulthood. Unfortunately, there has been a lack of integration across these areas in the past. As such, there is a need for a comprehensive review of this literature. When examined, a number of discrepancies in research findings across these areas can be identified. The current literature review and empirical investigation take a first step in reconciling discrepancies in the literature and make suggestions for future investigations to bring together these disparate areas. Five-year-old children, eight-year-old children, eleven-year-old children, and adults were tested under either incidental or intentional learning conditions for recognition of distinctive and typical own- and other-race faces. No differences were evident between the incidental and intentional learning conditions. However, evidence of a significant distinctiveness effect was found for all age groups. In addition, the cross-race effect was shown to be highly dependent on the distinctiveness of the faces. In fact, there was no evidence of a cross-race effect for the highly typical faces, while a reversal of the cross-race effect was found for the highly distinctive faces. In other words, for the highly distinctive faces, other-race faces were recognized more accurately than own-race faces, a contrast to previous research demonstrating more accurate recognition for own-race faces than other-race faces. The results from the current study suggest that the cross-race effect is more complex than previously thought and that distinctiveness is a powerful influence in face recognition across development.

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PREFACE

I would like to extend my most sincere gratitude to my advisor and mentor, Mark Strauss, for his support in my graduate training and this endeavor specifically. Your wisdom and guidance have proved invaluable, even when they were required long-distance. I am thankful for your continued support and mentorship.

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mom and dad especially for instilling in me a love of learning and the confidence and strength to accomplish my goals. I could have never gotten here without your guidance and encouragement over the years.

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1. INTRODUCTION

Face perception and recognition comprise one of the most fundamental skill areas in human cognition. The ability to perceive and recognize faces requires complex processing skills in addition to considerable experience with, and knowledge of, facial information (e.g., Collishaw & Hole, 2000; de Haan, Humphreys, & Johnson, 2002; Gauthier & Nelson, 2001). Despite the many studies that have been conducted on face perception and recognition, the domains of adult cognition, infancy, and childhood research seem to operate independently, with little attempt to integrate this research into a unifying theory of face perception. Theories of adult face perception almost never address how infants and children may develop these skills (e.g., Valentine, 1991); and developmental theories often address only the specific age group in which the researchers are interested (e.g., Carey, 1992; 1996; Nelson, 2001; 2003). Research within each population focuses on specific aspects of face perception and/or recognition and ignores other aspects. For example, during the newborn and early infancy periods, researchers are interested in whether individuals are able to recognize a familiar person from their environment, such as their mother (e.g., Bushnell, Sai, & Mullin, 1989; Pascalis, de Schonen, Morton, Dereulle, & Fabre-Grenet, 1995; Walton, Bower, & Bower, 1992), while research with older children and adults focuses on determining how individuals recognize unfamiliar faces (e.g., Johnston & Ellis, 1995; Newell, Chiroro, & Valentine, 1999; Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998). The current paper will integrate these two areas of research.

More importantly, when two areas of research address similar issues, their results often contradict one another or the relations between them are not considered by each other. This discontinuity is seen most clearly when comparing the infant and child research. Infancy research suggests that infants are developing a number of face recognition skills, such as the ability to form prototypes (de Haan, Johnson, Maurer, & Perrett, 2001); categorize gender (Newell, Strauss, & Best, 2003); and recognize unfamiliar faces (Pascalis, de Haan, Nelson, & de Schonen, 1998). Research with preschoolers and older children examines similar issues and claims that these skill areas are still limited in early childhood and continue to develop throughout most of childhood (e.g., Inn, Walden, & Solso, 1993; Wild, Barrett, Spence, O'Toole, Cheng, & Brooke, 2000). For instance, consider infancy research that has suggested infants are capable of processing faces in a configural manner in the first year (Cashon & Cohen, 2004; Cohen & Cashon, 2001; Thompson, Madrid, Westbrook, & Johnston, 2001). Research with young children does not find evidence of this processing ability until the preschool years or later (Schwarzer, 2000). Numerous other examples exist that similarly illustrate a lack of communication between research areas. Ultimately, the current research will pull together the research on the development of face perception and recognition and integrate it with the research on adults' face skills. The discrepancies in the results of the developmental research will be addressed and possible explanations for these discrepancies will be identified.

A primary issue that has been neglected in almost all research on face perception and recognition is the interaction of face processing strategies and the core base of face knowledge. Both processing strategies and the core knowledge base have received attention in the research on face perception and recognition, but the two have not been considered across different aged populations, nor have the relations between these aspects of face perception ever been addressed. Research on adult face perception and recognition has examined both face processing strategies and the knowledge base of individuals. The processing strategies that have been studied most thoroughly are configural and featural processing. As will be reviewed later in the paper, configural processing reflects processing of the second-order relations within stimuli, used mainly for face processing. Featural processing is a manner of processing stimuli that involves first-order relations within stimuli that is used for most other objects in the world. Definitions for configural and featural processing are neither clear nor unanimous in the area of face perception research. For the purposes of this paper, featural processing will refer to encoding and recognition of faces based on one or more individual features, with no reference to the relationships among these features. Configural processing, on the other hand, will refer to encoding and recognizing faces with special attention to “the specific spatial relationships among the individual facial features” (Schwarzer, 2000). Research has also shown that adults are experts with the faces in their environment. A demonstration of this expertise is shown in the research documenting how adults recognize faces of their own race more accurately than faces of another race (e.g., Devine & Malpass, 1985), which suggests that the knowledge base is learned from the environment. Faces from one’s own race are seen frequently and, therefore, the knowledge base for these faces is fairly complete. Faces from another race, however, are encountered less frequently and, thus, much less is known about these faces. The “other-race” faces are, thus, hypothesized to be stored in memory according to the values and distributions of the individual’s own race and not processed as efficiently, therefore not recalled as accurately.

The developmental face perception literature, on the other hand, has focused mainly on processing strategies and has largely ignored the impact of a growing knowledge base. Much of the research which addresses how infants and children develop face perception and recognition skills is concerned with changes in processing strategies. The developmental literature has shown that configural processing develops over the first six to seven years of life, with much variation in findings from different research programs, as will be discussed later in this paper. Carey has proposed a “processing shift” hypothesis in which children use featural processing strategies until they reach 7 to 10 years of age, at which time they switch to using more advanced, configural processing strategies (Diamond & Carey, 1977; Diamond & Carey, 1986). Changes in face processing skills are credited to this switch from featural to configural processing strategies. Although Carey (1996) poses the critical question of *what* is developing in face skills during early childhood, the proposed answers deal with processing changes, specifically the featural to configural shift in processing strategies during encoding.

In contrast to the numerous studies exploring the development of processing strategies in infants and children, there are very few studies which examine the growing knowledge base of faces. Valentine (1991, 1999) and colleagues (e.g., Lewis & Johnston, 1999; Newell et al., 1999; Rhodes, Byatt, Tremewan, & Kennedy, 1996) have demonstrated evidence of an extensive knowledge base of faces and their features in normal adults. This knowledge base, according to Valentine (1991), plays an important role in face perception and recognition. Experience with faces guides an individual’s encoding and subsequent recognition of a face, as the existing knowledge base is adjusted to incorporate this newly learned face. While the developmental literature certainly does not deny the existence of a knowledge base or its growth during infancy and childhood (e.g., Carey, 1996), the research has failed to examine the role that the *development* of this knowledge plays in face processing during childhood. Almost all of the infancy literature has focused on processing strategies or the development of specific skills, while ignoring the knowledge of faces that underlies these skills. Recently, a limited amount of research with children has addressed the role of face knowledge (e.g., Best, Strauss, Newell, Costello, & Gastgeb, 2004; Chance, Turner, & Goldstein, 1982; Johnston & Ellis, 1995; Newell, Strauss, Best, & Gastgeb, 2004). However, most of the research continues to focus on how processing strategies are changing, rather than the growth of the knowledge base.

Overall, the developmental literature seems to suggest that changes in processing strategies are necessary and sufficient to account for the development of face expertise. For instance, Carey (1992, 1996) indicates that the difference between child and adult performance in face perception and recognition tasks can be credited solely to differences in processing styles. The research has failed to address, however, whether increased knowledge of faces, their average values, and distributions plays a role in the development of face expertise. According to Valentine (1991), the way in which an individual stores faces in the face-space framework determines how efficiently these faces are recalled. Therefore, if infants and children are not storing faces in the same manner as adults, due to an insufficient knowledge base, their performance in face-related tasks will be impaired. However, children may also be storing faces in a completely different manner than adults, which might also account for the differences in performance between children and adults. Future developmental research needs to address the knowledge base of infants and children and the manner in which they are storing faces to determine the relative influences of processing changes and increases in knowledge base in the developmental changes in face perception.

Another possibility that has not been addressed in the face perception and recognition literature is an interaction between a growing knowledge base of faces and changes in processing style. It is conceivable that these two do not develop in isolation from one another, but that a change in one influences the other. For instance, an individual may experience new faces by simply adding them to his/her face-space framework until the current method of encoding faces is no longer efficient for recognition. At that point, new processing strategies that are better suited to the demands of the current developmental stage would be adopted. In concrete terms, young infants may process faces featurally, which is more suited to their situation, as very few faces need to be recognized. However, once the infant begins interacting within a wider social circle (or needing to remember faces in their wider social circle), s/he may find it difficult to effectively recall faces using a featural strategy. Therefore, this ineffective recognition performance may encourage the adoption of new strategies for processing faces (mostly likely unconsciously), such as a configural manner of processing. The literature on face recognition, specifically the “face-space” framework, has never addressed differences in processing strategies across development, and their role in the encoding, storage, and retrieval of faces.

The goal of the current research is to integrate the developmental research on face perception and recognition with what is known about adult face perception and recognition abilities. This will be done in one specific area of face perception: the developmental course of the cross-race effect of face recognition. The cross-race effect provides a platform to investigate important issues in the face perception literature. The comparison of recognition for same- and other-race faces addresses the contribution of both knowledge base and processing strategies, at individual time points in development, based on experience and domain-general memory development. The cross-race effect highlights the interaction of knowledge base and processing strategies. Previous research has demonstrated that other-race faces are processed in a featural manner at the same point in development when own-race faces are processed configurally. Therefore, the amount of experience with the group of faces determines the processing strategies utilized. In addition, the emergence of this effect can be examined across development, as the knowledge base of own-race faces increases. Thus, the following literature review will highlight evidence of changes in processing and knowledge base and discuss how changes in these two may interact in development.

First, the research on adult face skills will be briefly discussed, providing an overview of the most relevant issues, followed by a review of the research on face perception and recognition development. These research areas will be integrated into a consistent picture of development, addressing discrepancies in the previous research literature. Finally, this integration will be applied to an empirical question; the developmental course of the cross-race effect. The study described here will examine the development of the cross-race effect within a unique research paradigm designed to elicit a more naturalistic manner of face processing. Caucasian five-year-old children, eight-year-old children, 11-year-old children and adults will be tested under either incidental or intentional learning conditions for recognition of Caucasian (own-race) and Asian (other-race) faces within the context of a story.

1.1. Adult Face Recognition

1.1.1. The uniqueness of faces

Face recognition is one of the most critical human abilities. The ability to perceive and recognize faces is essential for identifying an individual as familiar or not, reading emotional expressions, and forming relationships, as well as many other important skills. Yet face recognition is an exceptionally difficult perceptual task. Faces are very complex stimuli in which minor variations have important implications for identity, emotional expression, and even gender. Despite the complexity of the task, adults demonstrate remarkable skills for perceiving and recognizing faces (e.g., Bahrick, Bahrick, & Wittlinger, 1975; Levin & Beale, 2000; O'Toole, Deffenbacher, Valentine, McKee, Huff, & Abdi, 1998). For instance, adults are able to recognize faces despite wide variations in pose, lighting, and expression (Newell et al., 1999). Also, individuals are able to recognize a face within ½ second, despite the fact that they have thousands of faces stored in memory (Carey, 1996). Bahrick et al. (1975) even showed that adults are able to recognize faces of classmates up to 35 years after graduation. In fact, adults perform so well in face recognition tasks that researchers have questioned whether faces are an innately "special" category of stimuli (e.g., Farah, Levinson, & Klein, 1995; Kanwisher & Moscovitch, 2000).

There is a substantial amount of research, both behavioral (e.g. Tanaka & Farah, 1993; Tanaka & Sengco, 1997; Thompson & Massaro, 1989; Ward, 1989) and neuropsychological (Farah et al., 1995; Kanwisher, McDermott, & Chun, 1997; Kanwisher, Stanley, & Harris, 1999; Kanwisher, Tong, & Nakayama, 1998), suggesting that the way we process faces is qualitatively different from any other object category. The behavioral research compares performance on object and face recognition tasks. For instance, studies have examined the degree to which individuals rely on configural versus featural processing in objects and faces. The research indicates that adults process faces in a more configural manner, while they process objects in a more featural manner (Tanaka & Sengco, 1997). These effects have been consistently found across different paradigms and in different labs (e.g., Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Farah, 1993; Tanaka & Sengco, 1997; Thompson, 1994; Thompson & Massaro, 1989; Ward, 1989). This effect is demonstrated by manipulating configural and/or featural information in stimuli and examining the influence it has on performance in face recognition tasks compared to object recognition tasks. Disrupting configural processing by inverting faces and objects, for instance, reveals that face recognition is disproportionately impaired in comparison to object recognition (e.g., Tanaka & Sengco, 1997).

Neuropsychological research supports the behavioral results in suggesting that the brain has a specialized region that processes facial identity (e.g., Farah et al., 1995; Kanwisher et al., 1997; Kanwisher et al., 1999; Kanwisher et al., 1998). Neuroimaging studies have consistently identified a specific region of the fusiform gyrus as responsible for face recognition, but not object recognition. This area, often called the Fusiform Face Area (FFA), reliably activates when individuals are performing face recognition tasks, but shows little to no activation during object recognition tasks (Kanwisher et al., 1997). In addition, prosopagnosia (face agnosia) is a neurological disorder which results in selective impairment for face recognition. Extensive testing with a small population of prosopagnosics reveals that the brain is damaged in the area of the FFA. Prosopagnosics cannot recognize familiar faces nor learn new faces (Farah et al., 1995). Also, the disorder selectively impairs face processing; object recognition appears to be near normal (De Renzi, 1986; Farah et al., 1995; Whiteley & Warrington, 1977). Together, this collection of behavioral and neuropsychological research has convinced many researchers that face processing is unique.

Despite this research literature, other investigators believe that there may be alternative explanations for the seeming “uniqueness” of face processing (e.g., Gauthier, Behrmann, & Tarr, 1999; Gauthier, Williams, Tarr, & Tanaka, 1998). They posit two related explanations for the apparent “specialness” of face recognition. First, faces may be unique in that all adults are experts in their knowledge of faces. Adults have had extensive, and meaningful, exposure to faces since birth. In order to compare individuals’ face recognition abilities with object recognition abilities, it would be necessary to use a category with which participants have also had very extensive experience or knowledge. Thus, individuals would need to possess expertise with a particular category of items in order to serve as an appropriate comparison category to faces. Gauthier and others (e.g., Diamond & Carey, 1986; Gauthier, Skudlarski, Gore, & Anderson, 2000) have conducted experiments with individuals who are experts with a particular category of objects (e.g., birds, dogs, cars). The results indicate that experts display similar behavioral and neurological effects with their category of expertise as typical adults do with faces. For instance, experts show an inversion effect with their objects of expertise, suggesting that experts process their objects of expertise in a more configural manner, similar to the way normal adults process faces (Diamond & Carey, 1986). Also, expert adults show activation in the FFA when discriminating their objects of expertise (Gauthier et al., 2000). The fact that the FFA shows activation in fMRI studies with experts, an area that is hypothesized to be specialized for face processing, suggests that there are many similarities between face processing and the processing of objects (for experts). Indeed, it has been hypothesized that this area of the fusiform gyrus is not specialized for face recognition, but that it is used for all perception and recognition tasks that require processing at a level of expertise. Gauthier and Tarr (1997) trained individuals to become experts in perceiving and recognizing an artificial category of objects, which they called 'greebles'. They (Gauthier & Tarr, 1997) demonstrated that novices appear to use featural processing strategies with these unfamiliar objects, while experts use more configural strategies. Tanaka et al. (1997) found similar results with car, dog, and biological cell experts. It is difficult to compare directly face recognition with 'greeble', car, dog, or cell recognition performance, because even individuals who are experts with 'greebles' and natural categories still have had significantly more experience with faces. However, the research with experts suggests that it is expertise or experience, not necessarily faces, which may be the critical factor in the experimental effects typically found in face research (e.g., inversion effect).

Second, the objects used in these studies as comparison stimuli are of a different level of categorical specificity than faces. Face recognition must represent subordinate-level categorization, as the differences between faces are very subtle, while sharing the same configuration (Tanaka, 2001). In contrast, most previous studies (e.g., Kanwisher, Chun, McDermott, & Ledden, 1996; Kanwisher et al., 1997) have used objects that represent different basic-level categories (e.g., dogs, cars, tables). The differences between basic-level categories are less subtle, and do not necessarily share a standard configuration while objects at the subordinate-level, such as different German shepherds or faces, all look very similar. Both faces and other subordinate-level categories share a basic configuration within a category. The critical differences that distinguish one subordinate-level object from another within the same category are the specific values of the features within the standard configuration. For instance, all faces have eyes, nose and mouth in the same configuration, but the exact size and positioning of these features is what distinguishes individuals. The similarity between them may force an individual to rely on more advanced processing strategies, such as configural processing. The differences between basic-level categories, such as different breeds of dogs, may be distinctive enough to be distinguished using a rough featural processing strategy (Diamond & Carey, 1986). Thus, the difference between an emphasis on featural processing with objects and configural processing with faces found in most previous studies may not be due to the distinction between faces versus objects, but instead a result of featural processing with basic-level versus configural processing with subordinate-level category stimuli (Gauthier et al., 2000; Tanaka, 2001). Ultimately, both of the above explanations may account for the performance differences between faces and objects. It is likely that not only do the objects need to be drawn from the same subordinate-level category, but also that individuals have a significant amount of experience with these objects (Diamond & Carey, 1986).

The discussion of the "specialness" of face processing continues to be an ongoing debate in the literature. Thus, it remains unclear whether face processing represents a unique ability, or whether adult face processing simply represents an area of perceptual expertise. A third alternative, however, is also possible. It may be that the fusiform gyrus is specialized for the very detailed perceptual task of face perception, but that as we gain experience with a particular category of objects we begin to recruit the fusiform gyrus, as it is the area of the brain best suited to fine-grained perceptual discriminations (Gauthier et al., 2000). Regardless of whether face processing is specialized in the brain, the mechanisms by which individuals perceive and recognize faces are critical areas of research, and shall be explored next.

1.1.2. Face recognition skills

Of particular interest to researchers of face recognition is the manner in which faces are stored in memory. Previous research on face recognition in adults has identified several important findings concerning the way adults store faces in memory. While researchers have attempted to explain each of these phenomena in the past, there was no recognition that they may be related or derived from common, underlying processes. A general framework, proposed by Valentine (1991), provides a unifying theory of face recognition. A discussion of how researchers independently explained this set of findings will be followed by a description of Valentine's (1991) face-space framework theory and the way in which it allows an integration of these findings.

Research has shown that adults remember distinctive faces more accurately than typical faces and that they are faster at identifying typical faces than distinctive faces in a face classification task (e.g., Bartlett, Hurry, & Thorley, 1984; Going & Read, 1974; Light, Kayra-Stuart, & Hollander, 1979). Several attempts have been made to explain this phenomenon. Light et al. (1979) proposed a two-component theory to explain the distinctiveness effect in which specific memories are accessed for distinctive faces whereas similarity to a prototype is used for typical faces. Bartlett et al. (1984), however, suggested that feelings of familiarity are responsible for this effect, where the presentation of a typical face results in a greater amount of familiarity than the presentation of a distinctive face. Finally, Valentine and Bruce (1986b) proposed a "prototype hypothesis" in which a prototype is extracted from all previously seen faces and individual faces are stored based on similarity to the prototype.

Explanations have also been identified for the other effects found in adult face recognition tasks. Adults have been shown to recognize faces of their own race better than faces from another race (Goldstein & Chance, 1980). Goldstein and Chance (1980) propose that this "other-race effect" is due to individuals' knowledge of the population of faces. They argue that as children develop they become more efficient at using a face schema for face recognition, but that with this increasing efficiency, they also become less able to apply it to unusual stimuli (i.e., inverted faces), or faces with which they have not had experience (i.e., faces from another race). Finally, adults have been shown to have more difficulty recognizing inverted faces than upright faces (Valentine, 1988). Diamond and Carey's (1986) study of inversion of faces and dogs demonstrated that an inversion effect could be found for stimulus categories other than faces as long as the individuals possessed expert knowledge with the stimulus class. Therefore, Diamond and Carey (1986) reinforced the idea that knowledge of faces previously experienced in the population played a role in face recognition. Additionally, Goldstein and Chance's (1980) "face schema" theory also accounts for the face inversion effect.

Although many of these explanations of the findings in the face recognition research have similar assumptions, they were considered in isolation for many years. Valentine (1991), however, proposed an experience-based face-space framework which pulls together all of the findings in the face recognition literature under a common theoretical framework. In this framework, faces are stored according to the values of their features. The framework is proposed to be an *n*-dimensional space representing all possible features of a face including single features (such as the nose), configurations (such as eye separation), and possibly outer features (such as hairline). The dimensions of the face-space framework depend upon an individual's experience with faces, although it is an inherent assumption of Valentine's theory that all of the feature distributions are normally distributed. Therefore, the center of this framework represents the central tendency of all the features. As an individual gains experience with faces, these faces are represented in the face-space framework according to the values of their features. With more experience, the distributions become more refined and the central tendencies become more accurate. More typical features (and therefore more typical faces) lie closer to the center of this framework. More atypical, or distinctive, features or faces fall along the outer edges of the framework (Valentine, 1991). Since features (and therefore faces) are assumed to be normally distributed, there should be a dense cluster of typical features/faces in the center of the framework whereas the distinctive faces should fall in more sparsely populated regions of the framework, along the perimeter (See Figure 1). The development of a face-space framework depends on experience and implies knowledge of the range of feature values in the environment. Valentine's theory necessitates that individuals be able to abstract central tendencies and the range of values from faces.

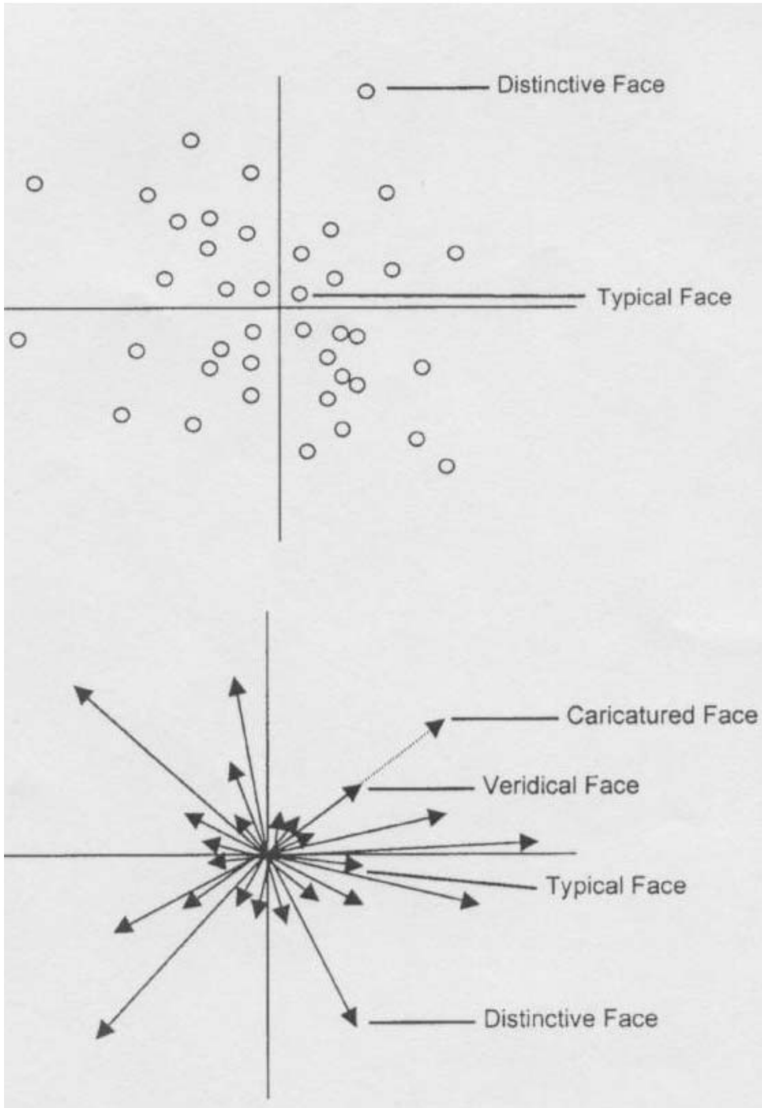

Figure 1 Face-space framework.

This framework can explain many of the previously identified effects of adult face perception and recognition. Research has consistently shown that distinctive faces are easier to remember than typical faces (e.g., Johnston & Ellis, 1995; Newell et al., 1999; Valentine, 2001), where "distinctiveness" is defined as whether the face would stand out in a crowd (Newell et al., 1999). When individuals are presented with both typical and distinctive faces in face recognition tasks, they are more likely to remember the distinctive faces (Light et al., 1979; Newell et al., 1999; Valentine & Bruce, 1986a). According to the face-space framework, the distinctiveness effect occurs because typical faces occupy a denser area of the framework (all lying near the center of the face-space). Distinctive faces, on the other hand, are found along the sparsely populated perimeter of the framework. Because the typical faces lie in a densely populated region, a previously seen face is more similar to many other faces, thus less likely to be remembered correctly. Similarly, it is more likely that a previously *unseen* typical face is falsely identified (Johnston & Ellis, 1995; Valentine, 1991).

Similarly, when faces are made more distinctive, as in a caricature, adults remember them quite accurately and recognize them very quickly (Rhodes, Brennan, & Carey, 1987). Caricatures are created by comparing the original face to an average face and then exaggerating those features of the original face that are most different from the norm (Byatt & Rhodes, 1998). Therefore, caricatures essentially make a face more distinctive than it was in its veridical form. Research demonstrates that adults are even able to remember caricatures more accurately than their veridical depiction if the face is familiar (Lewis & Johnston, 1999). Similar to distinctive faces, caricatures are remembered more easily because they fall in a more sparsely populated region of face-space.

The structure of the face-space framework relies on an individual's experiences with faces in the world. This explains why individuals tend to remember faces of their own race, which are highly experienced, better than faces of other, unexperienced races (Devine & Malpass, 1985; Goldstein & Chance, 1980; MacLin & Malpass, 2001). The faces which individuals have experienced in their world are those that determine the structure of their face-space framework. Therefore, if individuals have had limited experience with a particular race of faces, their face-space framework will not be configured to accurately encode these faces (Valentine, 1991). When participants are familiarized with faces from both their own racial group and another racial group they subsequently demonstrate better recognition for faces from their own race (e.g., Devine & Malpass, 1985; Goldstein & Chance, 1980). It is assumed that for most racial groups, experience with other-race faces is minimal. Individuals tend to have a well-defined face-space for discriminating those faces with which they have the most experience. Faces experienced in the world are encoded according to the dimensions of each individual's face-space. Therefore, other-race faces are likely to be encoded according to a system that is best suited to the feature distributions of one's own race. Without having a detailed representation of other-race faces and knowledge of the feature distributions of these faces, they tend to get lumped very closely together on the outer perimeter of the framework (Valentine, 1991; see Figure 2). When asked to recognize one of these faces, individuals have difficulty because of the high density of faces in the region in which they are stored.

Another aspect of face processing related to the "face-space" is the discrimination of gender. Adults are very good at classifying the gender of faces, and they do so very quickly (O'Toole et al., 1998). The discrimination of facial gender is based on a very fine-grained discrimination of the features that are maximally distinctive between males and females. These features include nose length, chin width, and eye to eyebrow distance (Brown & Perrett, 1993; Chronicle et al., 1995; Yamaguchi, Hirukawa, & Kanazawa, 1995). Not only are adults very good at classifying gender, they are also quicker to identify the gender of a face if that face has been rated as being very typical of its gender. For instance, a male face that has been rated by adults as being very masculine is classified as a male in a gender identification task significantly faster than a male face that has been rated as being somewhat less masculine (O'Toole et al., 1998). This typicality effect may also be explained according to the face-space framework. O'Toole et al. (1998) speculated that individuals may store faces according to gender-specific

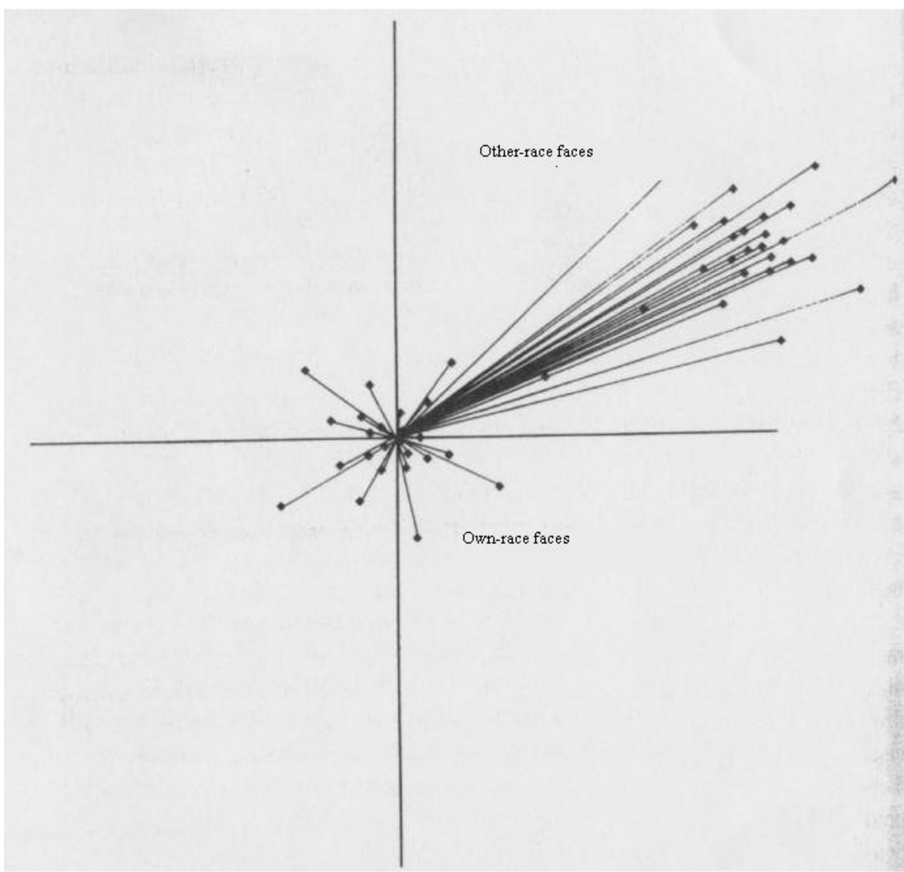

Figure 2 Representation of own-race and other-race faces in the world.

prototypes. It is possible that faces are stored in two different frameworks based on gender. If faces are stored based on gender-specific prototypes, then the distance from the prototype is indicative of how masculine/feminine a face is. Hence, faces that are more gender-typical are closer to the prototype and more quickly classified.

Finally, one of the most surprising findings in the face perception literature is the agreement across individuals and cultures in ratings of facial attractiveness (e.g., Berscheid, Dion, Walster, & Walster, 1971; Reis, Nezlek, & Wheeler, 1980). Despite intuitive beliefs that attractiveness is determined solely by personal preferences or cultural standards, it appears that attractiveness is also based on the "averageness" of faces (Langlois & Roggmann, 1990; Rubenstein, Kalakanis, & Langlois, 1999). Faces which have been artificially created by morphing multiple faces together to create an average face are rated by adults as more attractive than the individual faces which have created them (Langlois & Roggmann, 1990). Therefore, attractive faces are also the most average faces. Langlois and colleagues suggest that the agreement among adults in ratings of facial attractiveness indicates that adults have advanced knowledge of the average values of facial features. According to the face-space framework theory, attractive faces, being more typical, will be found close to the center of the framework. These faces are preferred because they represent the more average faces in the population (Rubenstein et al., 1999). Previous research with other perceptual categories such as colors (Martindale & Moore, 1988), objects (Whitfield & Slatter, 1979), and musical categories (Smith & Melara, 1990) also demonstrates a preference for the prototype of the category, more so than the less typical category members.

In summary, Valentine's face-space framework theory, a prevailing theory of face recognition, has helped guide a substantial amount of research investigating the face perception and recognition skills of adults (Byatt & Rhodes, 1998; Devine & Malpass, 1985; Johnston & Ellis, 1995; MacLin & Malpass, 2001; Newell et al., 1999; O'Toole et al., 1998). Overall, the face-space framework theory serves to explain many face recognition effects and integrate them into a collective theory. However, the processing strategies used in face recognition (e.g., configural vs. featural) and the development of this framework during infancy and childhood have not been addressed by the theory. As reviewed above, the recognition advantage for distinctive faces, other-race faces, and caricatures, the typicality advantage in gender classification tasks, and the preference for attractive faces are all hypothesized to be the result of the manner in which normal adults store faces. While our knowledge of face processing during adulthood is far from complete, a substantial foundation of research has been built thus far. It has been shown that face perception is based on experience and knowledge of the features of faces and that adults process faces in a more configural manner. Unfortunately, much less is known about the development of face expertise.

1.2. Development of face perception skills

The manner in which infants and children develop the ability to perceive and recognize faces provides insight into adults' processing and storage mechanisms. The developmental literature reveals evidence of processing changes throughout infancy and childhood and evidence of increasing knowledge of faces. This evidence will be presented in a chronological manner, charting the development of face expertise from the newborn period through childhood.

1.2.1. Infant Face Recognition

A significant amount of research has been devoted to tracking the development of face perception from birth. The infant research spans age ranges from infants who are only hours old up to about 18 months. Unfortunately, the research with newborn infants is often disconnected from the research with older infants and these two research areas have produced some disparate results that contradict each other. These disparate results will be addressed in this section.

1.2.1.1. Face perception by newborns. The research with newborns indicates that, at birth, infants possess basic face perception skills that help to guide their future knowledge of faces. The early experience of newborns may be critical for building a foundation of face knowledge. For instance, newborns are attracted to faces from hours after birth (Goren, Sarty, & Wu, 1975; Johnson & Morton, 1991). Visual tracking procedures present newborns with stimuli of varied amount of similarity to faces. These stimuli are slowly moved to one side and investigators measure how far infants will turn their heads to continue viewing the stimulus. Newborns track a face stimulus further than any other stimulus (Goren et al., 1975). However, it is unclear whether this preference is specific to faces, or whether it is due to the relative complexity of faces in comparison to the other stimuli presented. Easterbrook, Kisilevsky, Hains, and Muir (1999) indicated that infants are tracking faces based on their degree of complexity relative to other stimuli. Easterbrook et al. (1999) suggests that when infant vision is analyzed with a linear systems model, the spatial frequencies of a face are well suited to the newborn's visual capacities. Thus, their preferences are due to the appropriateness of the face as a stimulus, not "faceness" itself. It has been suggested that the newborn's visual preferences are dictated by a subcortical system that Morton and Johnson (1991) called CONSPEC. This is proposed to be an innate system which guides infants' attention to faces based on the basic stimulus properties of faces, and as such provides a basis for future learning. While under the influence of CONSPEC, infants are thought to be paying attention to faces without conscious control. It is through this experience that infants may learn the importance of faces and some basic knowledge of faces and their variations in the world. It is not until approximately six weeks of age that a cortical system, CONLERN, takes over the processing of faces. CONLERN uses conscious mechanisms to learn about faces (Morton & Johnson, 1991). Thus, it is clear that infants are attracted to faces from very early, possibly influenced by CONSPEC, but research has not determined the specific properties that attract infants' attention, whether it be specific to faces or some property of faces, such as complexity.

Another basic face perception skill that newborns demonstrate is the ability to recognize their mother's face within hours after birth, even when olfactory cues have been masked (Bushnell et al., 1989; Field, Cohen, Garcia, & Greenberg, 1984). Newborn vision is limited, however, to large and high contrast information (e.g., Kellman & Banks, 1998). Thus, recognition of the mother is probably based on features such as the outer contours of the face and the head shape. These are the features that newborns scan most consistently (Maurer, 1985). When these features are occluded, it is not until one month later that infants are able to recognize their mother (de Haan et al., 2001; Pascalis et al., 1998; Pascalis et al., 1995).

In contrast to the research demonstrating newborns' limited face perception skills, an alternative line of research claims that even newborns demonstrate a preference for attractive faces (e.g., Slater, Quinn, Hayes, & Brown, 2000; Slater et al., 1998). When newborns are presented with pairs of faces in which one face has been rated by adults to be attractive and the other has been rated as unattractive, newborns will look longer at the attractive face (Slater et al., 2000; Slater et al., 1998). While research suggests that infants and adults prefer attractive faces, this preference is assumed to be the result of a preference for faces that are most representative, or "average," for the population. In order to prefer a face based on its "averageness", one must know what is considered average for faces. Therefore, a preference for attractive faces that is based on typicality requires an individual to have formed a prototype of faces or to have at least a rudimentary face-space framework. However, newborns likely have not had enough experience with faces to have formed a prototype. In fact, the ability to abstract a prototype from a series of faces may not develop until at least three months of age (de Haan et al., 2001). Also, Langlois, Ritter, Roggmann, & Vaughn (1991) argue that a preference for attractive faces does not develop until six months of age. Thus, this early preference for attractive faces must be driven by some other mechanism not based on averageness or the ability to abstract prototypes. For instance, it is possible that this early preference for attractive faces is not driven by experience or knowledge, but by some other properties of attractive faces such as symmetry (e.g., Bornstein, Ferdinandsen, & Gross, 1981; Fisher, Ferdinandsen, & Bornstein, 1981) It is not yet clear, however, what mechanism accounts for this preference.

Overall, the face skills of newborns are limited by many factors. Most importantly, many difficult face perception tasks require perceptual skills that are beyond those available to newborns. For example, research on newborns' perceptual abilities has shown that infants cannot see fine details such as internal facial features. Also, eye-tracking studies have indicated that infants are not consistently scanning the internal features of faces until four months of age (Maurer, 1985). Finally, newborns have had very little experience with faces. Even if infants are born with multiple innate face perception skills, the advanced skills that older infants, children and adults possess require very extensive experience with a wide variety of faces. Therefore, newborns' face perception skills are impressive when taking these factors into consideration, yet quite narrow when considering all that still has to be learned.

1.2.1.2. Face perception by older infants. Infant research has demonstrated an emerging expertise with faces which begins from birth. Although face knowledge continues to develop well into childhood, the first year of experience with faces seems to be a period of rapid development, where infants are developing a strong foundation of face knowledge. By the end of the first year, infants are able to remember faces over an extended period of time (Fagan, 1973), abstract prototypes (de Haan et al., 2001), prefer attractive faces (Langlois et al., 1991), categorize gender (Newell & Strauss, 2002), and process faces configurally (Thompson et al., 2001). Each of these skills indicates vast experience with faces, knowledge of the average values and distributions of features, and advances in the processing of faces. These advances in knowledge and processing skills will be demonstrated in the following review of research with infants.

One of the most fundamental face perception skills is the ability to remember a face based on the internal facial features. Although newborns are able to remember a face based on external cues such as head shape (e.g., Bushnell et al., 1989), internal cues are more important for reliable face recognition because they are less vulnerable to change and represent the most detailed information in the face. As mentioned above, the ability to remember the internal features of a specific face for a short period of time develops as early as 1 month of age (de Haan et al., 2001). At this age, however, the memory is volatile and cannot be retained for a significant period of time. Fagan (1973) demonstrated that retention of a face in memory for a longer period develops by 6 months of age. While it is unclear what develops between one and six months that leads to advances in memory for specific faces, it is likely that the development involves changes in both processing and the structure of the face-space framework.

While researchers are still debating the specific nature of the face-space framework, it seems necessary for individuals to be able to compare faces across time, remember specific faces, and form categories of faces. Prototype formation necessitates each of these abilities.

Therefore, the emergence of the ability to form a prototype of faces indicates that infants are now able to accomplish each of these tasks. Hence, once the ability to abstract prototypes of faces emerges, infants should be able to begin forming a face-space framework. Although, Strauss (1979) demonstrated that infants are able to abstract a prototype from a series of faces at 10 months, a more recent study by de Haan et al. (2001) extended this ability to three-month-old infants. de Haan et al. (2001) explored the ability of one- and three-month-old infants to remember specific faces and to form prototypes of faces. Infants were presented with four successive faces during the familiarization period. During the test trials, infants were first presented with the prototype of the four familiarization faces paired with one of the familiarization faces. Preference for the familiar face indicates that infants find the prototype to be more familiar than a previously seen face, verification of prototype formation. Only the three-month-old infants demonstrated this preference. The infants were also presented with one of the four familiarization faces paired with a novel face to determine whether the infants were able to remember a specific face from the series. Both the one- and three-month-old infants demonstrated memory for a specific face by displaying a preference for the novel face. Therefore, this study revealed that the ability to form a prototype from a series of faces develops between one and three months (de Haan et al., 2001). Thus, by three months of age infants are beginning to learn the values of the faces they experience, abstract typicality distributions from this experience, and form a rudimentary face-space framework.

Closely related to the ability to form prototypes of faces is the preference for attractive faces. As noted previously, adults' ratings of facial attractiveness are based on the "averageness" of faces (Langlois & Roggman, 1990). In order to identify an attractive, or average face, one must first be able to abstract averages and typicality distributions from faces. Therefore, once the ability to abstract prototypes emerges, infants should also demonstrate knowledge of attractiveness. Langlois and colleagues (Langlois et al., 1991; Langlois & Roggman, 1990; Langlois, Roggman, Casey, Ritter, Rieser-Danner, & Jenkins, 1987) have conducted a series of experiments showing that, by six months of age, infants prefer those faces that adults have rated as attractive. Since infants have been shown to be able to abstract prototypes by three months, it is reasonable to expect infants to demonstrate a preference for attractive faces by six months. This research has demonstrated that six-month-old infants prefer attractiveness across a variety of different faces, including both genders and multiple races (Langlois et al., 1991).

As infants begin to gain knowledge of faces and form a more detailed face-space framework, other skills begin to come online. For instance, the ability to categorize gender using the internal features of faces is an advanced skill based on the discrimination of subtle details of faces, comparisons across faces, and the use of face prototypes. Quinn, Yahr, Kuhn, Slater, and Pascalis (2002) investigated the ability to categorize gender with three- to four-month-old infants. While infants familiarized with male faces demonstrated a novelty preference during test trials, infants familiarized to female faces did not show a novelty preference. Further investigations revealed that this novelty preference is derived from a preference for female faces generally. In fact, the preference for female faces reverses to a preference for male faces for infants whose primary caregiver is male. Therefore, this set of results suggests that early gender categorization is based on similarity to the primary caregiver. More importantly, these studies demonstrate the critical role that experience plays in the development of face expertise.

As described previously, adults demonstrate a typicality effect in gender categorization, in which more typical faces are categorized more quickly than less typical faces (O'Toole et al., 1998). The gender-related typicality of a face is determined by its distance in face-space from a gender-specific prototype. A recent study by Newell and Strauss (2002) indicated that categorization of gender in infancy emerges in relation to the development of the face-space framework. Five- and eight-month old infants were habituated to either male or female faces showing only the internal facial features in an infant-controlled habituation paradigm. The eight-month-old infants were able to categorize gender, but only with the most typical faces (i.e., very masculine or feminine faces; Newell & Strauss, 2002). A follow-up study extended the ability to categorize typical faces to six-month-old infants. However, even 11-month-old infants were unable to categorize gender when the faces were less typical (Newell et al., 2003). Therefore, when infants first begin to categorize gender, they can do so with only the most typical faces. This typicality effect is likely a reflection of the sampling of faces in the world of the infant. Infants are likely to have greater experience with more typical faces than less typical faces, and thus, develop gender categorization abilities with the most typical faces first. Typical faces are also the easiest to categorize based on the relative differences between the faces. For example, if you consider facial gender to be a continuum from masculine to feminine, then the most gender-typical (i.e., very masculine/feminine) faces will fall at the edges of the continuum and the less gender-typical (i.e., gender-ambiguous) faces will fall in the middle, where the two genders overlap (Figure 3). Thus, it is harder to classify the gender of these faces. The existence of a typicality effect in gender categorization during infancy supports the notion that infants are processing faces in a manner similar to adults and not categorizing gender on the basis of one or two features of the face.

Although adults are best able to process faces when presented in an upright orientation, very young infants do not show the same advantage for upright faces as adults do. Researchers have speculated that faces which are presented in an inverted orientation are not processed

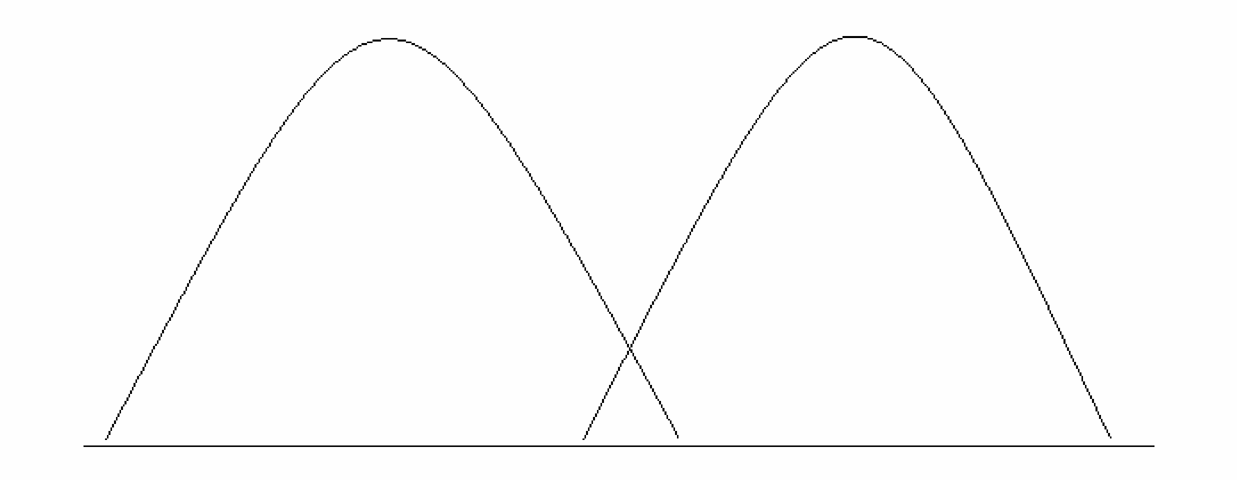

Figure 3 The distribution of male and female faces in the world.

configurally and, as such, are not remembered as well as upright faces. Inversion of faces is assumed to disrupt configural processing, driving a more featural method of processing faces (Bartlett & Searcy, 1993). This phenomenon has been credited more recently to the relative amount of experience that individuals have with upright versus inverted faces (Cashon & Cohen, 2004). It is well known that most of the face perception skills of adults are based on experience with faces. This experience is primarily with upright faces. Therefore, face perception skills for inverted faces do not develop. Young infants (less than 5-7 months of age), however, are equally good at recognizing both upright and inverted faces. One possible explanation for the difference between infants and adults is that infancy is the only time during development that individuals have a significant amount of experience with inverted faces (and all other orientations). Until infants are able to sit upright, they experience faces in every orientation. Therefore, it is possible that infants learn how to recognize faces in all positions (Cashon & Cohen, 2004). An alternative possibility is that infants are not equally *good* at recognizing upright and inverted faces, but that they are equally *poor* at recognizing upright and inverted faces. Infant face recognition performance is typically compared to chance performance, while adult performance is compared between conditions (i.e., upright vs. inverted). Therefore, adults are able to remember inverted faces at better than chance performance, but the performance with upright faces is significantly better than with inverted faces. Infants, on the other hand, are only able to remember both conditions better than chance; recognition of upright faces is not developed well enough to be significantly better than inverted faces. Whichever explanation best fits, a significant advantage for upright faces is not found until around seven months of age (Cashon & Cohen, 2004). Further support for the notion that by seven months infants are using configural face processing strategies is shown by Thompson et al. (2001), which demonstrated that seven-month-old infants attend to the configurations among features when comparing facial stimuli in which the features remained the same but the configurations among the features differed.

After reviewing the literature on infant face perception, it becomes obvious that infants are developing a number of important face skills during their first year of life. However, many skills have not fully developed (i.e., to adult-level). By comparing the infants' face perception skills to those of adults, it seems that infants have formed the basis of many foundational skills, but have not yet shown evidence of more advanced skills that require significantly more experience with faces.

A number of indicators of face expertise were identified in the review of adult face perception. Some of these skills have developed by the end of the first year, indicating a development of face expertise. Specifically, infants are able to form prototypes of faces (de Haan et al., 2001), prefer attractive faces (Langlois et al., 1991), process faces configurally (Cashon & Cohen, 2004) and categorize gender (Newell & Strauss, 2002). However, many skills have not yet developed. The recognition advantage for distinctive versus typical faces has only been investigated in one infant study. Preliminary data (Best et al., 2003) suggested that the recognition advantage is only evident in nine- and ten-month-old infants when recognition for very distinctive faces is examined. Sangrigoli and de Schonen (2004b) have shown that three-month-old infants recognize a single Caucasian face better than a single Asiatic face, but the effect disappears when familiarized with a series of three faces. Thus, there is limited evidence for the cross-race effect in infancy and it is dependent on experiences in the lab. The recognition advantage for caricatures has not even been studied yet. While there is little evidence of whether these skills develop during infancy, it is likely that these skills require years of experience with faces to develop. Therefore, more substantial evidence of these skills may not be found until the toddler or preschool years, as is true of gender categorization of less typical faces. Overall, there are a number of aspects of the face-space framework that seem to develop during infancy and childhood. While many skills are beginning to develop during infancy, the development of face expertise must continue to develop beyond infancy.

1.2.2. Child face perception

Although infants are developing a number of face skills during infancy, there is still much to be learned when individuals depart from the infancy period. By the time infants have reached the end of their first year, they are able to form prototypes of faces, recognize a face over an extended time, discriminate male versus female faces, and prefer attractive faces. What is left to be learned in childhood? Not only have some skills and face perception effects not yet reached adult-level, many others have not yet shown the beginnings of development. It is during childhood that most of the finishing touches are put on face perception skills and the more advanced skills of face expertise develop.

The following section will review the literature on children aged 2-13 years. Although research has examined face perception/recognition skills with children, little work has been conducted with toddlers and preschoolers. The few studies that have been conducted with young children indicate that this is a very important period in the development of face perception abilities. As with the review of the infancy literature, each of these important skills of facial expertise will be discussed in turn.

1.2.2.1. Face perception during the toddler and preschool years. Although many skills show rudimentary beginnings during infancy, these skills continue to show improvement throughout childhood until they reach adult-level. de Haan et al. (2001) demonstrated that infants as young as 3 months old are able to form prototypes from a series of faces, and treat the prototype as more familiar than one of the original faces from the familiarization series. However, Inn et al. (1993) indicate that the ability to form prototypes continues to develop through age six. Inn et al. (1993) examined the abilities of children aged three to six years old to form prototypes of a series of faces. Though all age groups viewed the prototype as familiar, the false alarm rate increased significantly with age. These results suggest that prototype formation abilities are continuing to develop from infancy through childhood. No study has yet determined when the ability to form a prototype reaches a performance level comparable to adults, although Inn et al. (1993) suggests that it is later than age six. This study reveals a developmental pattern that is seen consistently in many of the studies of face perception abilities in children; the foundations for skills are laid during infancy, but it is not until later in childhood that these skills are fully developed.

Another example of a face perception skill that continues to show improvement through childhood is gender categorization. As previously described, gender categorization begins to develop in infancy, but has not fully developed by the end of the first year. A study by Newell et al. (2004) with three- and four-year-old children has demonstrated that preschool children are able to categorize reliably the gender of both more and less typical faces. However, none of the children were able to categorize the faces with 100% accuracy, as adults are. In fact, accuracy levels ranged from 58% – 88%, depending on the typicality of the faces and whether hair was presented as a cue. The result indicated that both typicality and hair facilitated gender categorization. The typical faces which included hair were categorized most accurately, while the less typical faces with the hair occluded were recognized least accurately. The accuracy with typical faces with the hair occluded and the less typical faces with the hair included fell in between these extremes and were not significantly different from one another. The results from both infants and preschoolers show a clear pattern of increasing expertise. Individuals are gaining experience with faces, learning the values of their features, and understanding the differences between these features. The progression from categorizing only the most typical faces (i.e., during infancy) to inconsistently categorizing both more and less typical faces (i.e., during the preschool years) to consistently categorizing all faces (i.e., in adulthood) presents a clear picture of the development of facial expertise (Newell & Strauss, 2002; Newell et al., 2003). The development of gender categorization with the full range of faces in the world requires years of experience with faces and a well-developed face-space framework.

A similar pattern of development is seen in the memory advantage for distinctive faces. As mentioned above, adults demonstrate better memory for faces which have been rated as more distinctive than faces which have been rated as less distinctive (i.e., typical; Light et al., 1979). Preliminary data from our lab suggest that nine- to ten-month-old infants do not display a memory advantage for distinctive faces. A small effect seems to appear, but it is highly dependent on the level of distinctiveness of the faces (Best et al., 2003). However, preliminary data from a follow-up investigation with three- and four-year old preschoolers suggests a reliable recognition advantage for distinctive faces. This study presents six faces in an incidental learning phase and probes memory for each of these faces in a forced-choice task. This paradigm makes the task as easy as possible for the children by making the task more naturalistic. Also, the forced-choice test phase allows children to actively compare the novel and familiar faces. Overall, preschoolers showed better memory for the distinctive faces than the typical faces (Best et al., 2003).

If configural processing indicates advanced knowledge of faces, then it is likely an important area for exploring the development of face expertise. Much of the research with children indicates that the ability to process faces configurally does not develop until well into childhood, despite the research of Cashon and Cohen (2004), which suggests that configural processing is evident in seven-month-old infants. For instance, Schwarzer (2002) examined analytic and holistic processing in two- through five-year-old children. He found that all age groups processed faces using a single feature when presented in a task that allows them to choose their mode of processing, where analytic and holistic options are in competition. However, this study does not address whether configural processing abilities are present in two- though five-year-old children, it only suggests that they prefer to use featural strategies when they are available.

Another study examining configural processing in preschool children (Brace, Hole, Kemp, Pike, Van Duuren, & Norgate, 2001) revealed that two- to four-year-old children show an “inverted inversion effect” with faces. Preschool children showed faster reaction times to inverted faces than upright faces. While this effect seems to contradict the idea that children are processing faces configurally, a closer inspection of the data may reveal a different story. If the reaction times between upright and inverted faces were identical, it would indicate that these children are processing both orientations featurally. However, the significant difference between upright and inverted faces seems to indicate that preschool children are processing the two orientations in a different manner. Perhaps children are processing the upright faces configurally, but this strategy is not yet as efficient as the featural strategy, so that it requires more time and effort. This explanation can account for the data. In addition, the accuracy data reveals no difference for the orientations, so the children may be able to use the configural strategy successfully, just not as quickly.

Overall, there are very few studies that investigate face expertise with toddlers and preschoolers, despite the current research that suggests the skills which are present in infancy undergo important development during this time. The research conducted thus far indicates that this is a critical time period to examine; skills which are beginning to develop in infancy are almost at adult-level by childhood. Thus, important development must occur during the toddler and preschool years and is being missed by not conducting research with this age group. Practically speaking, it may be more difficult to recruit and test this age group, which may be why this population has been neglected in research. Compared to the infancy research, this research area suggests that some of the rudimentary skills are becoming more sophisticated during this time and also the recognition advantage for distinctive faces seems to be emerging during this time. As with infants, the recognition advantage for caricatures has not yet been investigated during this period of development.

1.2.2.2. Face perception by older children. During childhood, children are fine-tuning their face perception skills to become more adult-like. More advanced face skills that are indicative of face expertise are also developing during this period of development. As the following section will reveal, the later years of childhood are the period of development in which the “final touches” are put on face expertise. The foundation of facial expertise is in place before this time; it is during late childhood that skills are crystallized into their mature level. For example, it is during this time that holistic and configural processing strategies become very efficient and the strategies of choice for face processing. Also, the more advanced skills of face expertise are developing, such as the recognition advantage for other-race faces and caricatures.

Research with older children has shown that the ability to process faces configurally continues to develop well into childhood. Tanaka et al. (1998) employed a part-whole paradigm with children aged six through eleven years old. This paradigm presents faces during a learning phase, and then probes memory for a particular feature either in isolation or in the context of a whole face. An individual should be better able to identify a feature in the context of the whole face if s/he is processing the face configurally. Tanaka et al. (1998) showed that children from age six through eleven years process faces configurally. Therefore, by six years of age, children are efficient at configural processing in face perception tasks.

On the other hand, Schwarzer (2000) demonstrated that holistic processing is increasingly used by seven- and ten-year-old children. The paradigm employed by Schwarzer (2000) allows participants to choose their mode of processing when analytic and holistic processing are placed in competition. Participants can categorize a group of faces using either a single feature (i.e., analytic processing) or the relationship among all the features (i.e., holistic processing). Therefore, less advanced processing strategies may be more efficient for younger children and thus chosen more often (Schwarzer, 2000). However, when children are forced to process faces configurally, the evidence shows that they are capable of doing so (Tanaka et al., 1998). They simply become more efficient through development.

In addition, Johnston and Ellis (1995) showed significantly faster reaction times to categorize typical faces than distinctive faces in a face/non-face identification task with five-, seven-, nine-, eleven-, and thirteen-year-old children. However, an explicit task (based on recognition accuracy) employed by Johnston and Ellis (1995) revealed that five-year-old children did not show a memory advantage for distinctive faces. The results from Johnston and Ellis (1995) seem to contradict those found by Best et al. (2003). However, as will be discussed in a later section, the difference in implicit versus explicit paradigms may help to account for these differences. Implicit paradigms may be better suited than explicit paradigms for revealing skills that have not fully developed. Overall, this collection of results suggests that the memory advantage for distinctive faces begins to emerge in infancy but is not fully developed until after five years of age.

Directly related to the distinctiveness effect is the recognition advantage for caricatures. Caricatures are remembered as well as, or better, than their veridical depictions because caricatures are distinctive by nature. Only one study has attempted to chart the developmental course of the recognition of caricatures (Chang, Levine, & Benson, 2002). In this report, six-, eight-, and ten-year old children and adults were asked to rate five faces of different caricatured distortion on whether they were “most like” other faces or “most different” from other faces they’ve seen in the world. Caricatures, created by exaggerating the distinctiveness of faces; anticaricatures, created by making faces more average; and the veridical representation of each face were shown. Across all age groups, participants chose the anticaricatures as “most like” other faces and the caricatures as “most different” from other faces they’ve seen. However, the six-year olds showed the smallest distinctiveness effect, while the 10-year olds showed the largest distinctiveness effect. A second experiment by Chang et al. (2002) showed that reaction times in an identification task varied by caricature level for all participants (six-, eight-, and ten-year olds and adults). Caricatures were identified faster than anticaricatures and the veridical depiction. In addition, veridicals were identified faster than anticaricatures. On average, both children and adults chose a caricature as the best likeness for familiar faces, but an anticaricature as the best likeness for unfamiliar faces. This collection of results carries many important suggestions. First, the results support the notion that children are processing faces similarly to adults and using a face-space framework to organize their experiences. All age groups showed similar patterns of results, the effects simply became more pronounced as the children got older. Second, participants believed that the caricatures were the best representation of the familiar faces in the study, yet anticaricatures were the best representation of the unfamiliar faces. These results imply that very important differences exist between recognition processes for familiar and unfamiliar faces. Individuals seem to represent familiar faces in terms of distinctiveness, but are not able to do so with unfamiliar faces. This discrepancy, however, is rarely considered in the literature; most studies examine recognition of unfamiliar faces and assume that it generalizes to all the faces in the individual's environment. Finally, the ability to recognize caricatured faces as a representation of the veridical indicates that children as young as six years old are able to recognize the distinctiveness of faces, a fact supported by the work of Johnston and Ellis (1995) examining the distinctiveness advantage in face recognition.

According to the face-space framework, experience with same-race faces leads to the advancement of encoding strategies for these faces. More experience with own-race faces develops more extensive distributions of features and more accurate central tendencies for these features. A limited amount of experience with other-race faces, however, prevents the development of aspects of face-space related to this population of faces. As individuals become more proficient at recognizing own-race faces, the skills for other-race faces are not developing. Therefore, the developmental picture of the cross-race effect should follow a specific path. Early in development, when individuals do not have extensive experience with any race of faces, face recognition performance should be equivalent for all races of faces. As children gain more experience with faces of their own race, and develop more sophisticated face-space frameworks based on this experience, recognition performance should improve for own-race faces. Assuming a limited amount of experience with other-race faces, recognition performance for these faces should not improve with age. Thus, the difference in recognition accuracy for own-race and other-race faces should increase throughout development.

Investigations of the development of the cross-race effect have been limited and conflicting. The results of these few studies do not indicate a coherent developmental picture. Feinman and Entwisle (1976), the first study to explore the cross-race effect in children, explored the recognition abilities of Caucasian and African-American first-, second-, third-, and sixth-graders for both Caucasian and African-American faces. Feinman and Entwisle (1976) found a significant cross-race effect at all ages. In other words, Caucasian children more accurately recognized Caucasian faces while African-American children more accurately recognized African-American faces. More interestingly, children who had *more* contact with the other race displayed a *smaller* cross-race effect than children who were determined to have had little or no experience with the other race. Thus, this study clearly demonstrates the role of experience in the development of the cross-race effect.

The results of this initial investigation seem to clearly indicate that children demonstrate a cross-race effect by first grade. However, subsequent investigations by Chance, Turner, and Goldstein (1982) and Goldstein and Chance (1980) found conflicting results. Goldstein and Chance (1980) investigated the ability of Caucasian children in first through sixth grade to recognize Caucasian and Japanese faces. Children were familiarized with 10 faces of each race and tested with these 10 target faces and 20 distractor faces, with each race being tested on separate days. The results indicated that although recognition accuracy improved with age, there was no difference in accuracy between Caucasian and Japanese faces for all children. An adult comparison group did demonstrate the expected effect however, dispelling concerns about the particular stimuli used or the methodology.

Chance et al. (1982) conducted a follow-up study which extended the age range to include seventh- and eighth-graders in order to further explore when the cross-race effect might develop. This investigation included first- and second-graders, fifth- and sixth-graders, seventh- and eighth-graders, and adults. Again, all subjects were Caucasian and were tested separately on their ability to recognize Caucasian and Japanese faces. Individuals were familiarized with 16 target faces and tested with a total of 64 faces, targets and distractors. Similar to the Goldstein and Chance (1980) study, overall recognition accuracy improved across ages. The Age x Race interaction was significant, with only the youngest age group (first- and second-graders) not recognizing Caucasian faces more accurately than Japanese faces. This follow-up study suggests that the cross-race effect develops between second and fifth grade. The increase in the number of familiarization and test trials from the original study seems to have made the task difficult enough to demonstrate a cross-race effect.

A more recent study which explored the development of the cross-race effect was conducted by Pezdek, Blandon-Gitlin, and Moore (2003). This investigation explored the cross-race effect with Caucasian and African-American kindergarteners, third-graders, and adults. Pezdek et al. (2003) familiarized participants with a video of two men, one Caucasian and one African-American. Participants were tested for recognition 24 hours later. The target faces were presented in two race-specific line-ups, each with five distractor faces. As with the previous studies, recognition accuracy was found to increase with age, regardless of the race of the faces. In addition, the cross-race effect was found at all ages, and age did not interact with this effect. Therefore, the cross-race effect seems to be evident by five years of age according to Pezdek et al. (2003).

In support of the Pezdek et al. (2003) findings, Sangrigoli and de Schonen (2004a) also demonstrated the development of the cross-race effect at five years of age. Sangrigoli and de Schonen (2004a) employed a forced-choice task in which 3- to 5-year-old children were briefly presented with a face and asked to identify it after a 1000 ms delay when paired with an unfamiliar face. In this study, only the 5-year-old children displayed the cross-race effect, with Caucasian faces being recognized more accurately than Asian faces. The 3- and 4-year-old children recognized both Caucasian and Asian faces with equal accuracy.

Together, the developmental cross-race literature suggests that this effect arises between five and twelve years of age. The difficulty of the task (e.g., the number of faces, whether the task is discrimination or recognition) seems to be a factor in determining when the effect is evident. The findings reported on the development of the cross-race effect are consistent with that from the other indicators of expertise (i.e., distinctiveness effect, caricature advantage) showing a prolonged developmental period for the more advanced skills of face expertise.

Overall, the research with older children highlights a period of increasing expertise. Many face perception/recognition skills are already developed, but are being fine-tuned during this time. For instance, configural and/or holistic processing strategies are becoming more efficient and being used more frequently during this time (Schwarzer, 2000; Tanaka et al., 1998). Also, the recognition advantage for distinctive faces shows increasing strength in 5- through 13-year-old children (Johnston & Ellis, 1995). In addition, other indicators of face expertise are just beginning to develop during childhood. The cross-race effect of face recognition seems to be developing between seven and ten years of age (Chance et al., 1982) and the recognition of caricatures is present by six years of age (Chang et al., 2002). By childhood, the face-space framework seems to be fairly advanced. Children have an advanced knowledge of the features of faces and the distributions of their values. Together, these studies suggest that children display all the markers of face expertise by approximately ten years of age.

1.3. Integration

1.3.1. The Developmental Picture

While face perception has been a dominant area of research in many different domains, these literatures remain relatively independent from each other. The primary goal of this introduction was to integrate these literatures within a single theoretical model. The above reviews of the literature have identified several consistent findings that highlight the development of face expertise. However, many investigations have revealed findings that do not seem to be consistent with the developmental course of face expertise. A deeper analysis of these studies is required to understand why the findings do not fit into the general trend of development. An overview of the findings that are consistent with the general developmental course of face expertise will be discussed first, followed by a detailed discussion of the findings that seem inconsistent with this trend, including suggestions for why these particular studies find results which are inconsistent with the developmental course of face expertise.

The adult face literature, specifically Valentine (1991, 1999), has conceptualized adult face perception and recognition within a framework of expertise and advanced knowledge of the features of faces, their average values and their distributions. Evidence of this knowledge comes from findings that adults display typicality effects in gender classification (O'Toole et al., 1998); recognition advantage for distinctive versus typical faces (Light et al., 1979), same-race versus other-race faces (MacLin & Malpass, 2001), and caricatures (Lewis & Johnston, 1999); and universal agreement of attractiveness ratings (Langlois et al., 1987). In addition, the research on adult face processing suggests that adults use configural strategies to analyze faces (Bartlett & Searcy, 1993). Configural processing strategies reflect the use of second-order relations and require more subtle discriminations. The face-space framework approach has yet to describe how configural processing strategy use can be incorporated, or how the shift from featural to configural strategies occurs in development. It is possible that both featural and configural information is encoded in the face-space, but that configural information is used more frequently by expert perceivers, as it conveys more meaningful information. This is an empirical question that would require follow-up investigations to answer. Still, in order to clarify the development of face expertise, the developmental course of each of these skills needs to be identified. The developmental literature has examined the development of most of these skills, though not in the context of the development of face expertise. The development of these two components of face processing, processing strategies and expert knowledge, will be summarized in the following sections.

1.3.1.1. Development of processing strategies. The first component of the framework that is responsible for the advanced abilities of adults is the manner in which individuals' process faces. The adult research indicates that individuals process faces in a more configural manner, especially as individuals gain more experience with faces. The developmental literature has demonstrated a clear trend of increased use of configural strategies throughout development. For instance, infants show the ability to process faces configurally in some tasks, although the advantage for configural over featural processing is not yet at adult-level (Cashon & Cohen, 2004). Cashon and Cohen (2004) have demonstrated a significant advantage for upright faces in comparison to inverted faces by seven months of age. Toddlers and preschoolers also show the ability to process faces configurally, but tend to use featural strategies when they are available (e.g., Brace et al., 2001; Newell et al., 2004; Schwarzer, 2002). Schwarzer (2002) employed a paradigm which pitted analytic and holistic processing strategies against one another. Two- to five-year-old children chose to use analytic processing strategies more often. However, Brace et al. (2001) demonstrated that two- to four-year-old children process upright and inverted faces differently from each other. Older children (7-10 years old) show increased use of configural processing strategies, and begin using these strategies more efficiently (Schwarzer, 2000; Tanaka et al., 1998).

1.3.1.2. Development of facial knowledge. The second component of the framework is the complex knowledge of faces which develops as a result of experience. Adults have a highly advanced knowledge of the features of faces, their average values and the distribution of these values. Researchers such as Tanaka and Gauthier (e.g., Diamond & Carey, 1986; Gauthier & Nelson, 2001; Gauthier & Tarr, 1997; Tanaka, 2001) have consistently shown that adults possess expert knowledge of faces. The previous review of the developmental literature suggests that individuals gain a more extensive knowledge base of faces throughout development. For instance, gender categorization first develops with the most gender-typical faces and only later in development does it expand to include less typical faces (Newell & Strauss, in prep.). This trend is indicative of more advanced knowledge of faces and more experience with less typical faces. Early in infancy, individuals have had only a limited amount of experience with different faces. The limitation of gender categorization to only the most typical faces is likely due to very narrow gender category distributions, a direct result of their limited experience with a variety of faces (see Figure 4). The less typical faces in the world fall outside the individual's narrow gender categories. As the infant gains experience with a wider variety of faces, s/he also expands his/her gender categories. The older child's gender category distribution will look more like Figure 3, with a wider distribution of faces included and some degree of overlap where the less typical faces are found. When children learn to classify less gender-typical faces, they are doing so because they now have the knowledge of faces necessary to reliably discriminate these faces and recognize the featural differences between them.

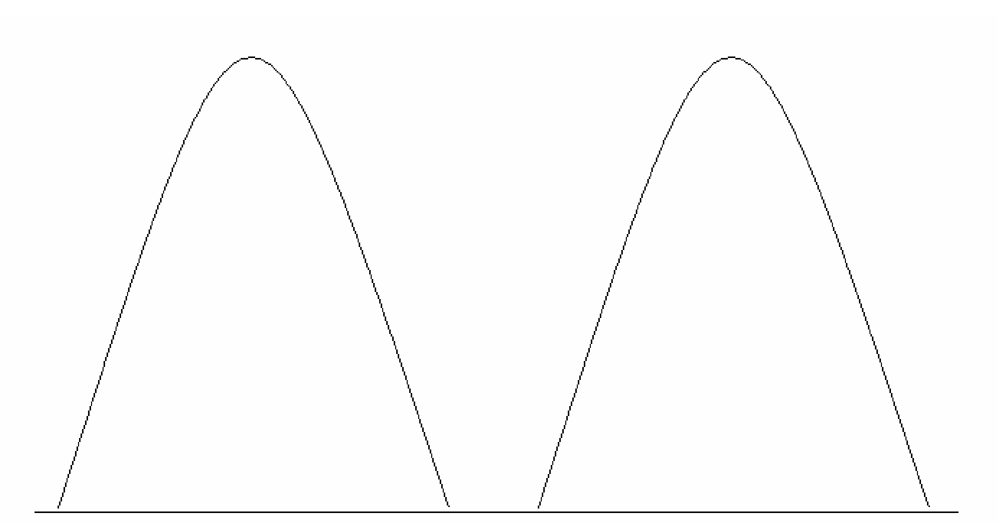

Figure 4 Young infants' representation of gender categories.

Another example of an increasing knowledge base can be seen in the development of the recognition advantage for distinctive versus typical faces. Best et al. (2003) indicates that recognition performance for distinctive and typical faces is essentially identical for nine- to ten-month-old infants. By age three- to four-years old, however, children are beginning to show a slight recognition advantage for distinctive over typical faces (Best et al., 2003), indicating a more complete knowledge of the faces in their environment. Future research would need to examine how the recognition advantage develops after the preschool years and when performance is comparable to adults.

Advanced knowledge of the faces of a population, and their features, is responsible for developing the ability to categorize the gender of faces; developing a recognition advantage for distinctive faces, same-race faces, and caricatures; developing the ability to form prototypes of faces; and developing a preference for attractive faces. The development of these skills is reflective of a growing face-space framework and more advanced dimensions of the framework. Each of the skills associated with the face-space framework theory develops as a result of increased knowledge and shows development of increasing performance in face perception or recognition tasks throughout infancy and childhood.

1.3.1.3. Interaction of processing skills and facial knowledge. Neither the adult nor the developmental literature has considered how the knowledge base of facial features and their distributions might interact with the processing strategies chosen to encode and recognize faces. The adult literature includes a great deal of research devoted to exploring the separate roles of knowledge base and processing strategies on face processing, but has not yet addressed the interaction of the two. Overall, the developmental literature has also ignored the potential interaction of these two components of face perception and recognition. For instance, the infancy literature has mostly focused on changes in processing strategies (and the development of specific skills such as the recognition of the mother's face). Researchers exploring children's face processing skills have also spent the majority of their efforts focused on changes in processing strategies, with very little attention paid to the growing knowledge base of faces.

As the face space framework becomes more dense (as the result of experience with more faces), important developments in face perception may occur. With a greater number of faces stored in face-space, individuals may discover that some areas of the face are more important for recognition than others. Many different programs of research on adult face recognition have explored which areas of the face are most important for face recognition (e.g., Fraser, Craig, & Parker, 1990; Haig, 1986; Sadr, Jarudi, & Sinha, 2003). However, little attention has been given to how this changes throughout development. Infants, who have a very limited knowledge of faces, tend to use less efficient areas of the face for recognition. Young infants (before four months) often are not scanning the internal features of the face (Maurer, 1985) and accomplish face recognition tasks (even with highly familiar faces such as the mother) by using qualities of the outer contours of the face and the hairstyle (e.g., Bushnell et al., 1989). As infants get older, and therefore gain more experience with faces, they begin to explore more informative regions of the face, such as the eyes and mouth (Maurer, 1985). Therefore, the infants' knowledge of faces may affect the manner in which they process faces. An exploration of the developmental course of feature areas used in face recognition could be very informative for discovering how the knowledge base is developing and its effect on processing strategies.

In addition, research investigating which areas of the face are important for face recognition does not take into account the research on distinctive face memory. Valentine (1991) and others have demonstrated that distinctive faces are easier to remember than typical faces. Although what determines the distinctiveness of faces is not well defined in the literature, it is usually discussed in terms of the distinctiveness of the entire face. However, distinctiveness may be determined by specific features or configurations of features. To date, researchers have not addressed how distinctiveness is determined in individual faces, nor how it interacts with which features of the face are important for memory. Although some general set of features may be important across all faces, there may be some variation within individual faces. For instance, most studies have shown that the lower face is less informative in face recognition (Fraser et al., 1990) and the chin in particular has never been cited as being important in face recognition. However, most adults remember the chin as an identifying feature of a particular celebrity, Jay Leno. The chin is a feature that is not often used in face recognition, but when it is particularly distinctive, it can be very useful for recognition. Therefore, individuals may possess a hierarchy of features/configurations to attend to in face recognition. If the features that are high in the hierarchy are very typical, then the individual may move down the hierarchy to identify features which are more distinctive. Also, if one feature/configuration is very distinctive (i.e., Jay Leno's chin), it may be elevated to the top of the hierarchy for that particular face. Unfortunately, this idea has never been formally tested.

In addition to changes in which areas of the face are used for recognition, other changes may occur as the face-space framework develops. Ultimately, the research on processing strategies suggests a shift from featural to configural processing strategies (e.g., Cashon & Cohen, 2004; Gauthier & Tarr, 1997; Schwarzer, 2000, 2002); configural processing use increases throughout development. This increased use coincides with increases in experience with faces, although this may not be coincidental. It seems possible that increased experience drives changes in processing. That is, as children gain more experience with faces, they might be forced to modify the organization of their face-space framework by expanding the distribution of a particular dimension, re-analyzing the central tendency of a particular dimension, incorporating a new dimension (feature or configuration) that has not been considered before, or chunking multiple dimensions (in a holistic manner). This re-organization will continue, coupled with the old processing strategy, until it is no longer useful. As the individual reaches such a point in development, the individual may shift processing changes in order to continue to develop the face-space framework.

1.4. Discrepancies in the research literature

Although the above review of the development of face perception and recognition skills seems to present a consistent developmental picture, there are some significant gaps in the research that need to be identified and explained. The gaps in the literature separate into two categories. The first type of gap is the result of research that has yet to be conducted. This type of gap does not represent a problem with the literature; it is simply a reflection of the youth of the research area. The second type of gap is a result of a discrepancy in the results of the research conducted thus far. This type of gap does represent a problem within the literature, and the possible reasons for these discrepant results will be addressed further.

1.4.1. Gap 1: Areas of missing research

The development of face processing skills is a relatively new area of research, with the first infancy face research conducted in the 1960's (e.g., Fantz, 1961). Since the investigation of the development of face perception and recognition is young, there is still a substantial amount of research that has yet to be conducted. This issue has come into focus after a careful review of the literature. There are many skill areas that have only been investigated in one or two age groups, thus not permitting a clear picture of the development of the skill across infancy and childhood, into adulthood. For instance, Langlois and colleagues have worked very hard to explore the development of the preference for attractive faces in infancy (e.g., Langlois et al., 1991; Langlois & Roggman, 1990; Langlois et al., 1987; Rubenstein et al., 1999). The evidence suggests that by six months of age, infants possess a preference for attractive faces and that this preference affects their social interactions by 12 months of age (Langlois, Roggmann, & Rieser-Danner, 1990). However, very little research on this topic has been conducted with children. There is no indication of how this preference changes from infancy to adulthood and whether this preference changes during childhood, when children are being exposed to cultural standards and developing individual preferences.

Similarly, the development of gender categorization has been well-documented from infancy through the preschool years (Newell & Strauss, in prep.). The research has indicated that infants first develop the ability to categorize the most gender-typical faces, around six months of age. By the ages of three- to four-years old, children are able to categorize both typical and less typical faces, but not at an accuracy-level comparable to adults. Sometime after the age of four years, children must develop the ability to categorize the gender of all faces in their environment at a level comparable to adults. However, the research demonstrating the development to adult-level has yet to be conducted.

Although the adult literature has reliably demonstrated the importance of research exploring the cross-race effect and the recognition of caricatures for demonstrating adults' face perception and recognition skills and exploring the face-space representation, very little developmental work has investigated these two skills. For example, by the age of six, children are able to identify caricatures faster than their veridical depiction and their anticaricatures

(Chang et al., 2002). However, no research prior to age six has ever been conducted. Therefore, there is no evidence demonstrating how children come to be able to identify caricatures. The research investigating the development of the cross-race is also impoverished. Very few studies have explored the development of this phenomenon; those studies that have been conducted do not convey a consistent developmental picture.

1.4.2. Gap 2: Discrepant results

Not all of the gaps in the developmental literature can be explained by identifying areas of missing research. Unfortunately, some of the research that has already been conducted contradicts one another. For instance, research on the development of configural processing of faces represents an area of research that has produced many discrepant results. The infancy research (e.g., Cashon & Cohen, 2004; Cohen & Cashon, 2001) has shown that infants display a recognition advantage for upright versus inverted faces by seven months of age. However, research with older children (e.g., Schwarzer, 2000; 2002) suggests that children do not actively use configural processing strategies until after seven years of age. How do we reconcile these discrepancies? One possibility is that the ability to process faces configurally develops in infancy, but that the efficiency with which children employ these strategies continues to increase throughout childhood. However, the research of Cashon and Cohen (2004) and Brace et al. (2001) are still in contradiction of one another. Cashon and Cohen (2004) suggests that infants show a recognition advantage for upright over inverted faces, yet Brace et al. (2001) suggests that preschoolers do not demonstrate this recognition advantage. The possible reasons for discrepancies such as this will be discussed in the following section.

Another possibility to consider in integrating the research on the development of configural processing is the way in which researchers define configural processing. As mentioned before, the research by Schwarzer (2000, 2002) investigates the development of *holistic* processing, while the research of Tanaka et al. (1998) explores the development of *configural* processing. There may be important differences between the definitions of these two terms. Configural processing suggests encoding the spatial distances between the features of the face, attending to the relationships among the individual features. Holistic processing, on the other hand, implies encoding the face as a whole, using the summation of all the features of the face. Holistic processing stresses a focus on the "Gestalt," where the whole of the face really is more important than the individual parts. It is difficult to try to equate these two methods of face processing. It may be that configural processing abilities, being able to represent the subtle differences within the face, must be present before holistic processing can develop. Thus, any generalizations made from research using different terminology must take these potential differences into account.

The research exploring the development of the recognition advantage for distinctive faces versus typical faces also demonstrates the pattern of discrepant results from infancy to childhood. Best et al. (2003) indicates that the recognition advantage for distinctive faces versus typical faces has developed by 3- to 4-years old. However, Johnston and Ellis (1995) do not find evidence of a recognition advantage for distinctive faces until seven years of age. The differences in results may be due, in part, to the differences in methodologies, although further work still needs to be conducted to ascertain the developmental course of the recognition advantage for distinctive faces.

Some of the research on the development of face processing skills reveals results that appear to show a consistent trend of increasing performance, yet a closer look at the research suggests that some discrepancies may exist. These research areas suffer from both types of gaps;

missing research and discrepant results. For instance, the research on the development of prototype formation seems to follow a clear developmental course. de Haan et al. (2001) demonstrated that 3-month-old infants are able to form a prototype from a series of four faces. During childhood the ability to form prototypes is present, but the false alarm rate increases from three to six years of age (Inn et al., 1993). It is difficult to try to compare the results of these studies. de Haan et al. (2001) did not investigate whether infants are able to form a prototype from more than four faces. Also, the looking time paradigms used with infants do not allow for the measurement of false alarm rates, which is the relevant measurement for the childhood research. Therefore, it is not possible to determine whether the false alarm rates found in childhood fit with the results revealed during infancy. Overall, although the empirical data do not directly contradict each other, further research needs to be conducted to determine the developmental course of prototype formation.

1.5. Reconciling the Discrepancies

While the majority of the face perception research, when taken as a whole, appears to paint a clear picture of the development of face expertise, a closer examination such as this identifies a few inconsistencies in the literature that need to be addressed. These inconsistencies tend to follow a specific pattern. Infants are found to be relatively advanced face processors, while young children still have not reached adult-level performance. While some studies imply very little development between infancy and childhood, others suggest that infants can accomplish tasks that children cannot. Are we to believe that during the toddler and preschool years individuals *lose* some face recognition abilities? How are we to resolve discrepancies such as this? There are several possible explanations for the discrepancies discussed previously, each of which will be discussed in this section.

1.5.1. Methodological Issues

When comparing competing research programs, one obvious place to begin is to look very carefully at the methodologies. There are two possible explanations for the identified discrepancies which are nested together under the broad category of methodological issues. The first explanation concerns stimulus issues; some stimuli have been used because they are practically implemented in the lab, and not necessarily because they are theoretically sound. The other issue concerns the task demands of the different methodologies and the influence this may have on performance.

1.5.1.1. Stimulus issues. Although developmental research has not given enough consideration to stimulus issues in the past, it is very important to consider the stimuli used in each study that was reviewed, especially in research with infants and young children. If the experimenter cannot give instructions to the participant, or there is a chance that the participant will not fully understand the instructions, the stimuli provided to the participant play an even more important role. Most of the developmental research uses stimuli that provide much less information than is available in the participant's everyday environment. For instance, most of the face perception and recognition research uses black and white photos or line drawings which include hair and clothing cues (e.g., Johnston & Ellis, 1995; Tanaka et al., 1998). These stimuli may be inappropriate for several reasons. First, the stimuli would be more realistic if color photos or dynamic videos were used. By making the task more realistic, the researcher is more likely to elicit the true abilities of the participant. Several different areas of perceptual research suggest that features of stimuli are more salient when motion is available (e.g., Bertenthal, Proffitt, & Cutting, 1984; Slater & Butterworth, 1997; Spelke, 1988). This finding also applies to face perception research (e.g., Arterberry et al., 2001). In addition, the inclusion of hair and clothing cues may also mask the true abilities of the individual. Hair cues are obvious and easily used to categorize or recognize faces. In fact, newborns are able to recognize familiar faces when hair cues are present, but not when they are occluded (Pascalis et al., 1995). However, using hair cues in a face perception or recognition task does not allow access to information about the individual's knowledge of facial structure and the fine differences between individual faces. By eliminating hair cues the research is truly measuring skills specific to faces. Finally, research (e.g., Friere & Lee, 2001) has shown that children have difficulty ignoring irrelevant stimuli such as clothing in face recognition tasks. If such extraneous information is available, children have difficulty ignoring this information to encode the finer details of the faces. Perhaps if the research with toddlers and older children addressed this issue, a more accurate representation of children's abilities would be determined.

1.5.1.2. Task demands. The other methodological issue to consider is the relative task demands of the infancy research compared to the childhood research. Little attention has been given to the differences in the tasks given to infants as compared to those given to older children. However, there are two key differences that may result in the discrepancies highlighted above. The first issue is that the tasks given to infants may be less demanding, and thus easier, than the tasks given to older children. Many of the infant studies employ paradigms that use paired comparisons (e.g., de Haan et al., 2001; Pascalis et al., 1998; Rubenstein et al., 1999), as opposed to the sequential recognition tasks used for older children (e.g., Inn et al., 1993; Johnston & Ellis, 1995; Schwarzer, 2000). Having both stimuli presented simultaneously in paired comparison tasks allows the individual to make active comparisons between the two. However, in sequential recognition tasks, the individual is required to keep the familiar stimulus in working memory to compare it to the test face, a task requiring more cognitive effort. Also, infant studies almost always employ looking time paradigms, which only require the infant to recognize that the novel face is interesting in some way, which does not necessarily mean that the infant is explicitly aware of why the stimulus is interesting (e.g., Cashon & Cohen, 2004; de Haan et al., 2001; Newell & Strauss, 2002). Research with older children requires a verbal or manual (i.e., finger pointing) response (e.g., Brace et al., 2001; Wild et al., 2000). Thus, the research with older children necessitates a more explicit knowledge than the infancy research. Keen (2003) compared performance of infants and toddlers on tasks of object and event representation. A similar discrepancy was found in which infants appear to have a clear understanding of object properties and event outcomes, whereas toddlers seemed to be lacking in this knowledge area. Toddlers were tested in a looking-time paradigm to equate task difficulty across infants and toddlers, and Keen (2003) discovered that toddlers demonstrated more knowledge in this task than during tasks that required a manual response. Therefore, the results from both infant and child research may be accurate, but measuring two different levels of knowledge or skills. This difference may be able to account for the discrepancies identified in the research on the development of configural processing.

The other way in which task demands for infants and children may not be comparable is in the general differences between the types of tasks given to infants versus children. Due to the limitations inherent to infancy research, all infant research paradigms are implicit tasks. On the other hand, very few of the research designs used with toddlers and older children tap implicit knowledge. Although researchers agree that face discrimination and recognition are automatic, implicit processes (Fallshore & Schooler, 1995), face recognition tasks used with children may be tapping explicit mechanisms, a different processing system than the one that is used naturally. Research such as that by Ellis, Ellis, and Hosie (1993) demonstrate that implicit memory develops before explicit memory. In fact, Ellis et al. (1993) indicates that implicit memory shows no improvement after age five, whereas explicit memory continues to develop during childhood. Therefore, explicit memory may not be developed enough to manage the cognitive load of a face processing task during childhood. Preschool children have been shown to be better at remembering information when presented in an incidental context (i.e., a shopping game) than in an intentional context (i.e., a lesson format; Istomina, 1975). However, the results from the Istomina study did not distinguish between whether children remembered information more accurately in the game context due to inherent properties of incidental learning, or because they received more exposure with the items. Replication attempts by Weissberg and Paris (1986) and Schneider and Brun (1987) strictly controlled for amount of exposure to the items in incidental and intentional conditions and did not find a difference in memory between the two conditions, despite overall age-related increases in memory.

Newman (1990) investigated the effects of intentional and incidental learning in preschool children while controlling for exposure time and also manipulating the items to be remembered. Children participated in either an intentional learning condition in which they were instructed to try to remember a set of items or an incidental learning condition in which they were simply told that they could do anything they wanted with the objects (pictures of objects for half of the children and small toys for the other half). A fifth condition, the laboratory condition, was a more direct replication of the intentional learning conditions of previous studies. Although there was not a main effect of condition (incidental vs.intentional), the means were in the predicted direction. The children did, however, demonstrate better memory for the items when presented in the "play" format than the "remember" format, but only when they were given toys to remember. Recall for the laboratory condition was not significantly different from the Remember-Pictures condition, its most similar comparison. The children were shown to have interacted with the stimulus materials at a deeper level (i.e., engaging in "functional" play rather than rehearsal) when presented in a play context as compared to an intentional learning context. Although counter-intuitive, preschool-age children appear to remember less information when explicitly instructed to remember something.

The advantage for incidental memory over intentional memory is not limited to young children. Experts in some fields have also been shown to remember information more accurately in incidental conditions than intentional conditions. For instance, Norman, Brooks and Allen (1989) compared memory for laboratory data with expert medical practitioners and novices. Participants were instructed to either try to provide a diagnosis from the data (i.e., incidental learning) or to try to memorize the data (i.e., intentional learning). The predicted Expertise x Condition interaction was significant. Novices were more accurate in the "memorize" condition, while experts were more accurate in the "diagnose" condition. Some other areas of expertise are also affected by task instructions. For instance, Adelson (1984) demonstrated that memory of a computer program differed by level of processing for experts and novices. Novices remembered the computer program more accurately in a "surface-level" task which involved simply describing the program while experts were more accurate in a "deep-level" task in which the participants were asked to identify the underlying goal of the program.

As children get older, the advantage for incidental over intentional memory is reversed (Smirnov & Zinchenko, 1969). Also, the advantage shifts from intentional to incidental memory as an individual gains expertise with an area of information (Norman et al., 1989). Thus, differences in incidental and intentional memory should be examined in the context of developing face skills. Adults are thought to be experts in face recognition (e.g., Diamond & Carey, 1986; Gauthier et al., 2000). Therefore, recognition performance should be better in incidental learning paradigms than intentional learning paradigms. Also, children should demonstrate a shift from better performance intentionally to incidentally as they gain expertise with faces. However, the majority of face recognition studies use intentional learning paradigms, and the two conditions have never been actively compared.

There is other evidence to support the assumption that explicit tasks are more difficult and may mask the true abilities of children. Evidence suggests that implicit, or unconscious, awareness reflects more advanced knowledge than explicit, or conscious, awareness. Young children demonstrate production deficiencies in their strategy use. In other words, young children have been shown to possess strategies, and that they try to use them, however they are poor at employing these strategies (DeLoache, Cassidy, & Brown, 1985). Preschool-age children are often thought to not be able to respond to instructions "to remember" in a task because they have difficulty utilizing strategies that they may know (Moely, Olson, Hawles, & Flavell, 1969). For instance, Siegler (2000) demonstrated that when children discover a new mathematical strategy, they first apply it without awareness (i.e., they report using another, less advanced strategy) before they verbally report using the new strategy. Also, research on the use of gestures suggests that advances in knowledge can be seen in gestures before speech (Church & Goldin-Meadow, 1986; Graham, 1999; Perry, Church, & Goldin-Meadow, 1988). When the gestures of children are examined during a task, children who are on the verge of discovering a new strategy will first show evidence of this strategy in their gestures.

Most of the studies on the development of face recognition employ intentional learning paradigms, which may tap into less advanced face processing skills. This problem may be exacerbated by underdeveloped face perception skills. If face perception and recognition skills are not fully developed during childhood (as suggested by most of the research conducted thus far), and explicit memory and processing strategies are not fully developed (e.g., Ellis et al., 1993), the interaction of these two factors may have very important consequences for performance in face processing tasks. The combination of these two weak skills may result in even poorer performance in face processing tasks than would be found if only one of these skills was being tested. Studies that are designed to examine the development of face processing skills may also be measuring the development of explicit processing without intending to. Research paradigms for children may place too much of an explicit processing requirement on participants. There is some evidence to suggest that implicit paradigms, being more naturalistic, allow access to more advanced processing of faces than explicit paradigms. The conflicting research on the development of the distinctiveness effect may be explained by considering the differences in task demands for the different studies.

1.5.2. Developmental course issues

The ideas put forth above concerning the methodological issues of infancy and childhood face research have never been tested. Perhaps a systematic investigation of these issues would reveal that the inconsistencies do not really exist, but only appear to be there due to differences in stimuli and task demands. If this is not true, what other explanations might exist for the discrepancies between infant and child face processing skills? Perhaps the discrepancies are not due to incompatible task comparisons, but instead a result of an incomplete picture of the developmental course of face perception. If the research that has been conducted thus far accurately reflects the development of face perception and recognition skills, then perhaps the developmental course of face processing skills needs to be examined more closely. There are two possible deviations from the traditional developmental course of a linear increase in skills that may explain the findings from the developmental face literature. One possibility is that there exists a U-shaped curve in the development of face processing skills. Infants may discriminate and recognize faces at a reasonably advanced level, but they may be doing so in a fundamentally different way than adults. If this is true, it is possible then that during childhood there is a shift in processing or focus such that children actually become worse than infants at more advanced face perception tasks. One suggestion concerning the potential difference in processing has been suggested by Susan Carey. Her research (e.g., Carey & Diamond, 1977) suggests that infants and young children may be processing faces using featural processing strategies, and that a shift occurs during childhood to configural processing. More recent research (e.g., Cashon & Cohen, 2004; Thompson et al., 2001) suggests that infants are able to process faces configurally, but there may be other changes in face perception/recognition skills during childhood that could account for a U-shaped curve in development. For instance, there may be an important shift in the structure of one's face-space framework that could account for a U-shaped curve in development.

The other variation in the developmental course of face perception and recognition that may exist is a slowing of development between infancy and childhood. Infants have been shown to possess an impressive number of face skills by the end of the first year (e.g., Cashon & Cohen, 2004; de Haan et al., 2001; Langlois et al., 1991; Newell & Strauss, in prep.). It is possible that the skills that infants possess at the end of their first year are sufficient to allow them to function in their environment. During the toddler and preschool years, children may focus on developing other skills that are necessary for interacting in their world, such as language skills. Thus, individuals may put the development of more advanced face skills on hold until later in childhood, to allow more cognitive effort to be focused on the development of more important skills. Further research would need to be conducted to explore the true developmental course of face expertise.

2. EXPERIMENT

The present study was designed to address some of the important issues raised in the previous review. Unfortunately, not all of the identified issues can be addressed in one empirical endeavor, and thus one critical area was addressed in this study: the cross-race effect of face recognition, which provides a platform to begin a systematic program of research to address many critical issues in the face recognition research literature. The current study aimed to resolve three issues. The first issue that the present study addressed was the lack of research on the development of face knowledge. The cross-race effect reflects an individual's advanced knowledge of the faces which s/he has experienced most often. This effect has not been examined in enough detail in past research to adequately address when this effect arises in development. In other words, when do children possess a sufficient amount of knowledge about the faces in their environment that they recognize these faces with greater accuracy than other-race faces?

The second critical issue raised in this paper that has not been addressed previously in the face recognition literature is the role of incidental versus intentional learning tasks. Incidental learning tasks allow comparisons across infancy and childhood research, as infancy research paradigms cannot be made intentional. In addition, incidental learning paradigms may also more accurately measure face recognition skills. Face recognition is an incidental process in the natural environment; however, the majority of the previous face recognition studies have not employed incidental learning paradigms. Young children have been shown to display better memory for items when presented in an incidental learning paradigm than an intentional learning paradigm (Istomina, 1975). In addition, experts remember information from their area of expertise more accurately under incidental learning conditions than intentional learning conditions. The current study actively compared the effects of incidental versus intentional learning paradigms. Based on previous research, incidental learning conditions were predicted to elicit more accurate recognition for young children and experts (i.e., adults). This pattern may not hold true for the older children, when intentional learning is more efficient (e.g., memory strategies are effectively utilized) and face recognition skills have not yet reached the level of expertise.

The third and final issue is one that has been addressed in the adult literature, yet never considered in the developmental literature; the role that distinctiveness plays in the cross-race effect. Distinctiveness has been shown to play an important role in the recognition of faces, in studies of the recognition abilities of both children and adults. Distinctive faces are more accurately recognized than typical faces. Valentine and Endo (1992) did not find an interaction between distinctiveness and race; however, distinctive faces were recognized more accurately than typical faces regardless of race. The distinctiveness effect has been shown with children as young as three years old and thus should be a factor to consider when testing recognition memory. Unfortunately, distinctiveness has yet to be addressed in the developmental studies exploring the cross-race effect. None of the studies have measured the distinctiveness of the stimulus faces, therefore it is impossible to ascertain whether the samples were equally recognizable. Studies which test only one race of participant, however, risk the possibility that distinctiveness of the stimuli is affecting the results. For instance, if the own-race faces are more distinctive than the cross-race faces, a stronger cross-race effect would emerge due to the distinctiveness effect of recognition. In addition to distinctiveness needing to be well-controlled, the role of distinctiveness in cross-race recognition is also an important question to address in terms of face-space development. It has previously been assumed that other-race faces are stored in the perimeter of the own-race face space. Other-race faces are stored according to the typicality distributions of own-race faces and, therefore, are clustered closely together in the perimeter. Previous research (e.g., Valentine and Endo, 1992) has shown that the recognition advantage for distinctive faces is present in both own- and other-race faces. Thus, distinctiveness appears to be important in recognition of both own- and other-race faces. However, an exploration of the interaction between distinctiveness and race is an important avenue of research that has not been considered in the developmental literature. It may be possible to see the emergence of a distinctiveness effect in other-race faces later than for same-race faces, as it takes more years of experience with faces to learn the typicality distributions of other races of faces.

Previous research exploring the role of distinctiveness in cross-race recognition has typically utilized a collection of faces which vary in distinctiveness based on adult raters. However, none of these studies have looked at recognition of the extremes of distinctiveness, the most and least distinctive faces in a stimulus pool. Cross-race recognition accuracy for these faces may yield different results than those previously found. Individuals with a moderate amount of contact with other-race faces may have begun to extract a typicality distribution, accounting for the distinctiveness effect found by Valentine and Endo (1992). As there are fewer other-race faces in a typical face space, the very distinctive other-race faces may occupy a less densely populated region of face space than the very distinctive own-race faces. If individuals do possess a rudimentary knowledge of typicality distributions for other-race faces, and store them accordingly, then the very distinctive other-race faces may be recognized more accurately than the very distinctive own-race faces.

Finally, the present study examined the development of the cross-race effect within three development groups and compared these age groups to a group of adult participants. Subtle changes in the developmental course of this skill may be revealed by examining it across six years of development. As mentioned, it is unknown whether face recognition skills follow a linear developmental path, a U-shaped developmental curve, or plateau at some point before steadily increasing again. The data collected from the three developmental time points examined in the present study were predicted to implicate a particular developmental course.

The present study examined the development of the cross-race effect with 5-, 8-, and 11-year-old children. The children were familiarized to both Caucasian (same-race) and Asian (other-race) faces, and recognition accuracy for the two racial groups was compared. The stimulus faces also varied in distinctiveness; half of the faces were distinctive and half were typical. The participants were told a story which included the familiarization period, a short delay, and the test trials. In order to compare incidental and intentional learning paradigms, half of the participants were randomly assigned to one of two experimental conditions. In the intentional condition, participants were given specific instructions that they would need to memorize the faces they saw in the story. In the incidental condition, participants were not given specific instructions to memorize the faces, but were simply asked to observe a story.

To summarize, the present study predicted that increased experience with same-race faces would lead to the development of face recognition skills. Moreover, this increased experience would not transfer to all faces, thus leading to the formation of the cross-race effect. This led to five predictions that were tested in the current study:

1) With age, the overall recognition performance would improve as a result of increased face recognition skills.

2) The cross-race effect would emerge between five and eleven years of age, and the strength of the effect would increase with age.

3) An overall distinctiveness advantage would be evident at all ages.

4) Recognition accuracy would be better for participants in the incidental learning condition than the intentional learning condition, at least for the 5-year-old children and the adults.

5) The cross-race effect would possibly be more pronounced in the incidental learning condition, as this condition allowed for more advanced and naturalistic processing of faces.

The current study was designed to test these predictions.

2.1. Method

2.1.1. Participants

The participants included five-year-old children (n=33, M=68.2 months), 8-year-old children (n=30, M=103.9 months), 11-year-old children (n=21, M=135.4 months) and adults (n=30). None of the participants reported any major developmental disorders. The children were recruited from rural elementary schools and child care centers in western Pennsylvania, an area which is composed of almost exclusively Caucasian individuals. Children were recruited by a letter sent home to the parents. The adult participants were recruited from undergraduate classes at the University of Pittsburgh.

2.1.2. Stimuli

One hundred female Caucasian faces were extracted from the CD version of Akira Gomi's art book *Americans 1.0*. One hundred female Chinese faces were digitized from Akira Gomi's art book *Yellows 3.0*. All faces were forward-facing with a neutral expression and a common background. All faces were presented in black and white, to eliminate any obvious differences in skin tone between the Caucasian and Chinese faces. The Caucasian faces were rated for distinctiveness by Caucasian undergraduates. The Chinese faces were rated for distinctiveness by Chinese volunteers. Faces were rated on a scale from one to seven, with one meaning "least distinctive" and seven meaning "most distinctive". Raters were told that a distinctive face is one that would stand out in a crowd because of unusual or unique features or overall appearance. Raters were also told that a typical (or non-distinctive) face is one that would not stand out in a crowd, but have an overall average or typical appearance. The eight most distinctive and eight least distinctive faces from each race were selected. The mean ratings for these 32 faces were entered into a 2-way (Race x Distinctiveness) ANOVA. There was no main effect of race (F=0.91, p>.1). There was a main effect of Distinctiveness (F=608.2, p<.001). There was also a significant Race x Distinctiveness interaction (F=4.57, p<.05). This interaction was due to a marginal difference between the Asian and Caucasian ratings for the distinctive faces (F=3.97, p=0.06), with Caucasian faces being slightly more distinctive (M=5.68, SD=0.36) than Asian faces (M=5.27, SD=0.42), but no difference between the Asian and Caucasian ratings for the typical faces (F=0.88, p>.1). The digitized faces were cropped in Microsoft Picture It! so that hair and clothing cues were eliminated. This process ensured that the participants were not able to recall the faces based on idiosyncratic features such as hairstyle or specific clothing items (see Figure 5).

Figure 5 Examples of stimulus faces

2.1.3. Apparatus

Participants were tested individually, in a quiet room. The stimuli were presented on a 15-inch computer monitor using Microsoft Powerpoint presentations. Participants were seated a consistent distance from the computer monitor, approximately 24-30 inches away. The experimenter was seated next to the participant and recorded answers from the recognition trials on a coding sheet.

2.1.4. Procedure

Participants were brought into a quiet room and told that they were going to hear a story that they would be asked to participate in. Participants were randomly assigned to one of the two conditions, in which faces were introduced either incidentally or intentionally. Participants in the incidental condition were told only that they would hear a story and to pay attention to it.

Participants in the intentional condition were told that they would hear a story and they would need to try to memorize the faces of the individuals in the story, as they would be tested on these faces at the end of the story. Both conditions were identical except for the instructions given before the story.

The storybook format allowed each face to be introduced individually in a naturalistic manner. The story involved a social setting (i.e., a birthday party for the children and a sorority competition for the adults) in which each face was introduced as a party guest/competition participant. The participants were encouraged to engage in the story through verbal interaction with the experimenter about particular aspects of the story. For instance, participants were presented with a two-dimensional model of a table and chairs and were asked to choose a seat for each guest/competitor as she arrived at the door. This procedure elicited participation in the story and ensured that attention was given to each familiarization face.

Both stories were age-appropriate and structurally similar, except for the themes. Both stories consisted of three main sections. The first part of the stories was used to introduce the faces, when the participant "meets" the party guests. The second part was a delay period in which the stories continued, but the participant did not see the faces during this time. The final part of the stories consisted of a recognition test in which the participant was asked to identify which faces were seen at the party.

2.1.4.1. Birthday party story

FAMILIARIZATION PERIOD

During the familiarization period, the participants were introduced to the "party-goers" individually. Each participant was introduced to 16 female faces (8 Caucasian and 8 Asian). After a brief description about the birthday party, the guests began arriving. Participants in the incidental condition were not told anything about remembering the guests; they were simply introduced to each guest as a part of the story. Participants in the intentional condition, however, were told that it was very important to study each face carefully, as they would have to identify the party guests later in the story. Each guest was greeted at the door by Sally, the birthday girl. The face of each guest was presented alone on screen (see Fig. 5) for a consistent amount of time (approximately five seconds) while Sally greeted the guest. The appearance of the face (i.e., cropped in tight circle, black and white) was integrated into the story by explaining that the child was seeing the face through the peephole in the door.

DELAY PERIOD

After all the guests arrived, the party began. During the birthday party, Sally and her friends played a variety of games and participated in several different activities, such as eating birthday cake (see Figure 6 for example of activities). Each slide depicted a scene of an activity at the birthday party, but the only faces that were shown were clip art pictures. Thus, the children were not re-exposed to the familiarization faces during the delay period. The length of the delay period varied slightly with each participant, depending on the level of interaction of the child. However, the average length of delay was three to five minutes. In the story, the last activity at the birthday party was the opening of the gifts. However, before Sally could open her gifts, she discovered that someone had taken all of her birthday gifts. The participants were then asked to identify which girls were at the birthday party to help Sally's mom and dad figure out who had taken the presents.

TEST PERIOD

After the delay period, the children were asked to identify the sixteen faces they met at the beginning of the story. They were presented with 32 faces, sequentially, and asked whether each face was present at the party. There were an equal number of Caucasian and Asian faces. Thus, the test trials consisted of 50% old and 50% new faces. Each face in the test trials were presented full-screen, identical to the presentation of familiarization faces (see Figure 5).

Figure 6 Example of birthday party activity.

2.1.4.2. Sorority party story. The sorority party story was used for the adult participants. The story was very similar in structure to the birthday party story, to allow for accurate comparisons between age groups. The 32 female faces were the same faces as those used in the children's story. The adult story also included familiarization, delay and test periods.

FAMILIARIZATION PERIOD

The story began by introducing the plot of the story, a competition between pledges and sisters for a sorority on campus. Each familiarization face was introduced as a competitor upon arrival at the party. In the incidental learning condition, participants simply saw each face arrive at the party and were not told anything about remembering these faces. In the intentional learning condition, participants were told that it was very important to study the faces carefully, as they would have to recognize these faces later in the story.

DELAY PERIOD

After all the guests arrived for the competition, there were a series of activities that the pledges and sisters competed in, such as table tennis and miniature golf (see Figure 7 for example of activities). During this time, the familiarization faces were not seen again. All faces presented in the delay period were cartoon drawings from clip art. While the exact amount of time elapsed during the delay period varied slightly with each participant, the average amount of delay was three to five minutes.

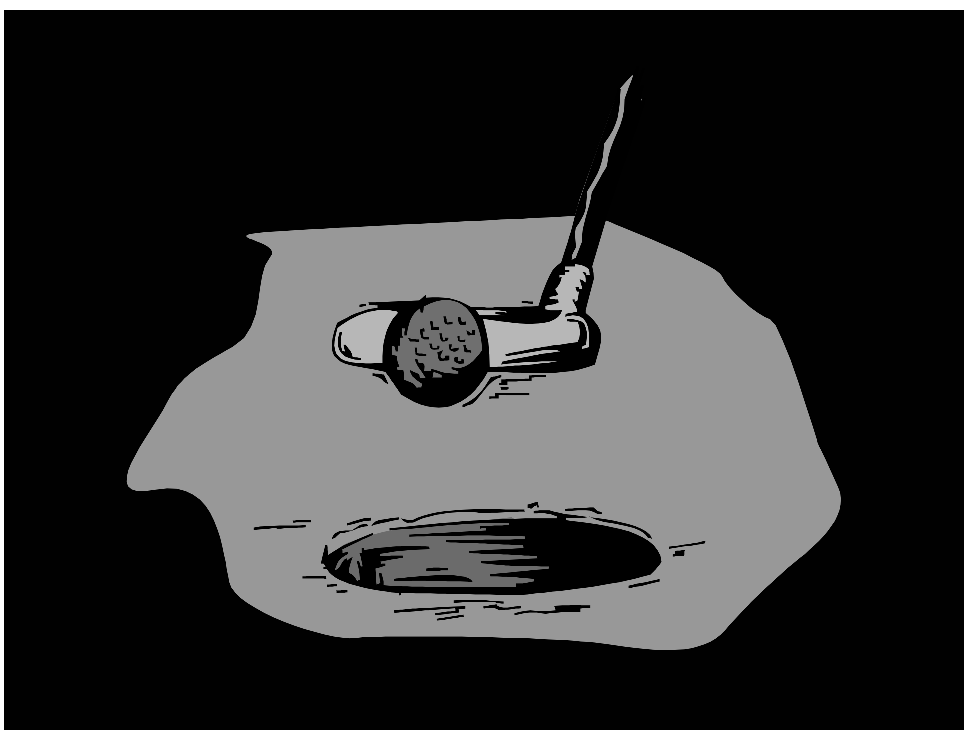

Figure 7 Example of sorority competition activity.

TEST PERIOD

After the delay period, the participants were asked to identify, from a series of faces, which were the pledges that participated in the competition. Similar to the ending of the children's story, at the end of the competition it was discovered that someone took the trophy for the competition. The participant was asked to help identify who participated in the competition to minimize the suspect list. A series of 32 faces were presented to the participants (16 old, 16 new). The participants were asked to identify each face as "old" or "new."

2.2. Results

Table 1 provides estimates of percent correct, hits, false alarms, discrimination accuracy (A'), and response criterion (B''). Percent correct was analyzed as a general indicator of performance, while A' was analyzed as a more sensitive measure of accuracy, taking response bias into account. The hit rate provides a measure of participants' recognition of previously seen faces. The false alarm rate provides a sense of which faces were misidentified as "old", in other words, which faces were confused most often. The results for each measure will be discussed separately.

2.2.1. Percent correct

Calculation of percent correct provides an overall sense of recognition accuracy, without taking into account the participant's response bias. To examine between-subjects effects, the total percent correct out of the 32 test trials was entered into an Age (5-, 8-, and 11-year olds and adults) x Gender (Male vs. Female) x Condition (Incidental vs. Intentional) ANOVA. There was a significant main effect of age ($F(3,111)=3.87$, $p<.05$). Post hoc Tukey HSD tests revealed that 5-year olds (M=63.0, SD=0.02) performed significantly worse than adults (M=71.0, SD=0.02;

Table 1: Dependent variable scores for all age groups

			Percent Correct	Hits	False Alarms	A'	B''
5-year olds	*Caucasian*	Distinctive	67.0(16.5)	.57(.31)	.26(.24)	.71(.21)	.28(.74)
		Typical	57.2(15.9)	.65(.31)	.52(.28)	.60(.25)	-.31(.73)
	Asian	Distinctive	70.1(15.3)	.64(.30)	.24(.24)	.78(.17)	.25(.79)
		Typical	57.5(16.1)	.57(.27)	.42(.28)	.59(.23)	.01(.71)
8-year olds	*Caucasian*	Distinctive	68.8(17.9)	.58(.28)	.21(.23)	.75(.21)	.47(.64)
		Typical	63.8(18.4)	.65(.25)	.37(.25)	.67(.25)	.01(.67)
	Asian	Distinctive	78.8(13.2)	.67(.27)	.12(.16)	.85(.12)	.53(.70)
		Typical	62.9(19.6)	.66(.25)	.38(.31)	.68(.24)	.00(.76)
11-year olds	*Caucasian*	Distinctive	76.8(17.3)	.60(.33)	.11(.15)	.81(.18)	.67(.46)
		Typical	64.9(17.5)	.62(.31)	.35(.30)	.66(.24)	.14(.82)
	Asian	Distinctive	79.8(12.8)	.71(.23)	.14(.19)	.86(.12)	.44(.71)
		Typical	56.5(17.9)	.63(.28)	.49(.24)	.60(.24)	-.19(.66)
Adults	*Caucasian*	Distinctive	77.5(17.5)	.70(.24)	.13(.16)	.86(.13)	.57(.51)
		Typical	67.9(15.3)	.67(.20)	.32(.25)	.73(.18)	.13(.73)
	Asian	Distinctive	77.9(12.1)	.68(.22)	.10(.14)	.88(.08)	.53(.68)
		Typical	65.0(19.3)	.67(.25)	.37(.30)	.69(.24)	.01(.73)

p<.01), marginally different from 11-year olds (*M*-69.2, *SD*=0.02; *p*<.1), but not significantly different from 8-year olds (*M*=69.4, *SD*=0.02; *p*>.1). There was a marginal Age x Condition interaction (*F*(3,111)=2.42, *p*=0.07) due to greater accuracy in the intentional condition (*M*=74.7, *SD*=0.03) than the incidental condition (*M*=64.0, *SD*=0.02; *t*=2.75, *p*<.05) for the 8-year olds only. All other age groups performed similarly in the incidental and intentional conditions (*p*>.1). As there was no main effect of or interactions with gender, this factor was collapsed in subsequent analyses.

The average percent correct was calculated for the distinctive Asian faces, the typical Asian faces, the distinctive Caucasian faces, and the typical Caucasian faces (see Table 2). These scores were entered into a Race (Asian vs. Caucasian) x Distinctiveness (Distinctive vs. Typical) x Age (5-, 8-, 11-year olds and adults) x Condition (Incidental vs. Intentional) Mixed ANOVA. As predicted, there was a significant main effect of distinctiveness (*F*(1,113)=68.83, *p*<.001) with distinctive faces being recognized more accurately (*M*=74.8, *SD*=0.01) than typical faces (*M*=62.0, *SD*=0.01). There was also a significant main effect of age (*F*(3,111)=3.47, *p*<.05). Post hoc Tukey HSD tests revealed that 5-year olds (*M*=63.0, *SD*=0.02) performed significantly worse than adults (*M*=71.9, *SD*=0.02; *p*<.05), marginally different from 11-year olds (*M*-69.4, *SD*=0.02; *p*=.08), but not significantly different from 8-year olds (*M*=69.2, *SD*=0.02; *p*>.1). Finally, there was a Race x Distinctiveness interaction (*F*(3,111)=6.42, *p*<.05). This interaction was due to Asian distinctive faces (*M*=0.77, *SD*=0.01) being recognized more accurately than Caucasian distinctive faces (*M*=0.73, *SD*=0.02; *t*=2.60, *p*<.01), but Asian typical faces (*M*=0.61, *SD*=0.02) being recognized as accurately as Caucasian typical faces (*M*=0.64, *SD*=0.02; *t*=1.13, *p*>.05). Therefore, a difference between own- and other-race faces was only found for the distinctive faces, where Asian faces are recognized more accurately than Caucasian faces.

2.2.2. Hits

The average numbers of hits was computed to provide an estimate of how often participants correctly identified a face that they had seen previously. To examine between-subjects effects, the total hit rate was entered into an Age (5-, 8-, 11-year olds and adults) x Gender (Male vs. Female) x Condition (Incidental vs. Intentional) ANOVA. There was a significant main effect of condition ($F(1,113)=6.12$, $p<.05$) due to more hits in the intentional condition ($M=68.0$, $SD=0.02$) than the incidental condition ($M=60.3$, $SD=0.02$). As there were no main effects or interactions for gender or age, these factors were collapsed in subsequent analyses.

The average hit rate was calculated for the distinctive Asian faces, the typical Asian faces, the distinctive Caucasian faces, and the typical Caucasian faces. These scores were entered into a Race (Asian vs. Caucasian) x Distinctiveness (Distinctive vs. Typical) x Condition (Incidental vs. Intentional) Mixed ANOVA. There was a significant main effect of condition ($F(1, 113)=7.06$, $p<.01$) with participants in the intentional condition remembering the faces more accurately ($M=67.9$, $SD=0.02$) than participants in the incidental learning condition ($M=60.2$, $SD=0.02$). There was also a marginal Race x Distinctiveness interaction ($F(3, 111)=3.13$, $p=0.08$). This interaction was due to distinctive Asian faces being recognized more accurately ($M=0.67$, $SD=0.26$) than distinctive Caucasian faces ($M=0.61$, $SD=0.29$; $t=2.03$, $p<.05$). There was not a significant difference in hit rate for typical Asian ($M=0.63$, $SD=0.26$) and Caucasian ($M=0.65$, $SD=0.27$). No other main effects or interactions were significant.

2.2.3. False Alarms

The false alarm rate provides a measure of how frequently "new" faces were incorrectly judged to be "old" faces. To examine between-subjects effects, the total false alarm rate was entered into an Age (5-, 8-, 11-year olds and adults) x Gender (Male vs. Female) x Condition (Incidental vs. Intentional) ANOVA. There was a significant main effect of age ($F(3, 111)=3.34$, $p<.05$). Post hoc Tukey HSD tests revealed that 5-year olds had significantly more false alarms ($M=0.36$, $SD=0.03$) than the adult participants ($M=0.23$, $SD=0.03$; $p=.01$). No other age groups were significantly different from each other. There were no main effects or interactions of gender or condition; these factors were collapsed in subsequent analyses.

The average false alarm rate was calculated for the distinctive Asian faces, the typical Asian faces, the distinctive Caucasian faces, and the typical Caucasian faces. These scores were entered into a Race (Asian vs. Caucasian) x Distinctiveness (Distinctive vs. Typical) x Age (5-, 8-, 11-year olds and adults) Mixed ANOVA. There was a significant main effect of distinctiveness ($F(1, 113)=157.94$, $p<.001$) with distinctive faces eliciting fewer false alarms ($M=0.16$, $SD=0.01$) than typical faces ($M=0.40$, $SD=0.02$). There was also a significant main effect of age ($F(3, 111)=3.77$, $p<.05$). Post hoc Tukey HSD tests revealed that five-year-old children responded with more false alarms ($M=0.36$, $SD=0.03$) than adults ($M=0.23$, $SD=0.03$; $p<.01$); there were no other differences between age groups.

2.2.4. A’

The A’ statistic is a nonparametric measure of signal detection which uses both the hit rate and the false alarm rate for calculation (Rae, 1976). A’ scores generally range from .5, representing chance performance, to 1.0, representing perfect accuracy. Rae’s correction was used to correct for false alarm rates that exceeded hit rates. To examine between-subjects effects, the overall A’ was entered into an Age (5-, 8-, 11-year olds and adults) x Gender (Male vs. Female) x Condition (Incidental vs. Intentional) ANOVA. There was a significant main effect of age ($F(3, 111)=3.32$, $p<.05$). Post hoc Tukey HSD tests revealed that 5-year olds were significantly less accurate ($M=0.70$, $SD=0.02$) than the adult participants ($M=0.79$, $SD=0.02$; $p<.05$). No other age groups were significantly different from each other (p>.1). There were no main effects or interactions of gender or condition; these factors were collapsed in subsequent analyses.

The A' statistic was calculated for the distinctive Asian faces, the typical Asian faces, the distinctive Caucasian faces, and the typical Caucasian faces. These scores were entered into a Race (Asian vs. Caucasian) x Distinctiveness (Distinctive vs. Typical) x Age (5-, 8-, 11-year olds and adults) Mixed ANOVA. As predicted, there was a significant main effect of distinctiveness (F(1, 113)=63.25, p<.001) with distinctive faces being recognized more accurately (M=0.81, SD=0.01) than typical faces (M=0.65, SD=0.02). There was also a significant main effect of age (F(3, 111)=5.31, p<.05). According to the Tukey HSD post hoc tests, five-year-old children were significantly less accurate (M=0.67, SD=0.02) than adults (M=0.78, SD=0.02; p<.01); there were no other differences between age groups. There was also a significant Race x Distinctiveness interaction (F(3, 111)=5.64, p<.05). The interaction was due to distinctive Asian faces being recognized more accurately (M=0.84, SD=0.01) than distinctive Caucasian faces (M=0.78, SD=0.02; t=3.58, p>.01). There was no difference between recognition of typical Asian (M=0.64, SD=0.24) and Caucasian faces (M=0.67, SD=0.23; t=0.83, p>.1).

2.2.5. B"

B" is a measure of response criterion. B" scores can range from -1.0 (strongest bias to respond "old") to +1.0 (strongest bias not to respond "old"). A B" score of 0 represents a response pattern without any bias to respond either way. To examine between-subjects effects, the overall B" was entered into an Age (5-, 8-, 11-year olds and adults) x Gender (Male vs. Female) x Condition (Incidental vs. Intentional) ANOVA. There were no main effects or interactions of the between-subjects factors. Since there were no main effects or interactions of age, gender or condition, these factors were collapsed in subsequent analyses.

The B” statistic was calculated based on hit and false alarm rates for the distinctive Asian faces, the typical Asian faces, the distinctive Caucasian faces, and the typical Caucasian faces. These scores were entered into a Race (Asian vs. Caucasian) x Distinctiveness (Distinctive vs. Typical) Mixed ANOVA. There was a significant main effect of distinctiveness (F=62.53, p<.001) with participants judging the distinctive faces more conservatively (M=0.45, SD=0.05) than typical faces (M=-0.03, SD=0.05). There was no main effect of race and no Race x Distinctiveness interaction (p>.1).

In summary, all the dependent measures suggest that participants typically became more accurate in face recognition across age, as evidenced by significant main effects of age. Also, there was a very strong distinctiveness effect found in all five measures of recognition, with distinctive faces were recognized more accurately than typical faces. Finally, a significant cross-race effect arose from distinctive Asian faces being recognized more accurately than distinctive Caucasian faces.

2.3. Summary and Conclusions

The current study explored the development of the cross-race effect at four different ages from five years of age to adulthood in a unique research design that addressed the role of distinctiveness in the cross-race effect. The current study represents a small step towards addressing some of the discrepancies highlighted previously. The results cited here have important implications for face recognition research in general, and the role of race and distinctiveness in particular. The storybook design represents a new paradigm that allows for a more naturalistic measure of face recognition performance, although it has yet to be directly compared to the more traditional methods of face recognition research. In addition, the results indicate that the interaction between race and distinctiveness is more complex than previously thought.

As predicted, age was a significant between-subjects factor for all markers of recognition, indicating that face recognition skills increased with age. Interestingly, the only significant difference in performance was between the five-year-old children and adults. Previous literature has suggested, however, that face recognition skills are not fully developed, or adult-like, until ten years of age or older. The present study demonstrates that there are no differences in recognition performance from eight years of age and older, which suggests that face recognition skills may be reaching adult-levels earlier than previously suggested. The unique paradigm utilized in the current study makes the task of face recognition more naturalistic. This may be one reason why face recognition performance was similar to adults as early as eight years of age in the current study.

Although it was predicted that there would be a difference in performance between the racial groups, surprisingly, there were no significant differences between Asian and Caucasian faces. Participants at all ages recognized the Asian and Caucasian faces with a similar degree of accuracy. It is possible that the lack of differences in recognition of Asian and Caucasian faces may be related to the very strong effect of distinctiveness found in this study. That is, children and adults showed better memory for distinctive faces than typical faces, regardless of the race of each face. The main effect of distinctiveness was highly significant ($p<.001$) for all measures of recognition. Furthermore, there was no interaction between Age and Distinctiveness, which suggests that the recognition advantage for distinctiveness was apparent by 5 years of age. This is an important finding by itself. Previous research (Gilchrist & McKone, 2003; Johnston & Ellis, 1995) has not found evidence of a distinctiveness effect in recognition accuracy until seven years of age. Johnston and Ellis (1995) demonstrated that the distinctiveness effect was not at adult-level until 9 years of age. Again, the unique design of the current study may have allowed for more naturalistic recognition performance, and may be a more accurate reflection of face recognition skills.

Although there was not a main effect of Race, there was, however, an interaction between Race and Distinctiveness, which was due to distinctive Asian faces being remembered more accurately than distinctive Caucasian faces. Recognition of the typical faces, on the other hand, did not differ between racial groups. The sampling of faces used in this particular study may have revealed an interesting phenomenon in face recognition that has not been considered previously. The current study demonstrated that the cross-race effect reverses for very distinctive faces and disappears for very typical faces. The faces for the distinctive and typical stimulus groups for the current study were selected from the extremes of a distribution of distinctiveness ratings for each race group. This method of choosing stimuli was highly effective for ascertaining the role of distinctiveness in face recognition; however, it may have masked any potential cross-race effects. The distinctive faces were recognized so well and the typical faces were recognized so poorly (although not at floor or ceiling levels), that the race of the face did not affect recognition performance overall. Valentine and Endo (1992) also found a distinctiveness effect regardless of race of face; however, the overall recognition of own-race faces was still better than other-race faces. On the other hand, previous research exploring the role of distinctiveness in the cross-race effect has utilized faces within a range of distinctiveness, or has not specifically examined the extremes of the distributions (e.g., Chiroro & Valentine, 1995). Perhaps when recognition of the most typical and most distinctive faces of each race is compared the cross-race effect becomes more complex than previously thought. The results cited here support this proposition.

When an individual must recall very typical faces, performance is quite similar for other-race and own-race faces. There are two potential explanations for this phenomenon. The first explanation relies on the relative density of these areas in the individual's face space. Even though there are fewer other-race faces overall in the face space, the very typical other-race faces may be densely clustered if a typicality distribution for these faces is incorporated into the face-space. Thus, own- and other-race typical faces will be recognized at a similar level of performance because they both lie in densely clustered regions of the face space. The other explanation for the absence of a cross-race effect for very typical faces is that the very typical own- and other-race faces may be approaching a universal norm, such that they are equally typical in relation to this universal norm. For example, the very typical Asian faces may be considered typical in relation to not only other Asian faces, but to all faces in the world. Therefore, these faces should be recognized with similar accuracy regardless of race.

On the other hand, when an individual recalls highly distinctive faces, a cross-race effect does emerge in the opposite direction as predicted (i.e., other-race faces are recognized more accurately than own-race faces). Very distinctive other-race faces are easier to remember than very distinctive own-race faces because there is much less competition from surrounding faces for the highly distinctive other-race faces. These faces are found in the outskirts of the other-race faces, which are already located on the perimeter of the face space. Therefore, these faces are located on the very edge of the face-space and have few close neighbors to compete for recognition. Thus, these faces should be recognized most accurately in a paradigm which compares the most and least distinctive own- and other-race faces. The results from the current study support this proposition; the highly distinctive other-race faces were recognized most accurately.

Thus, the cross-race effect may be very dependent upon the distinctiveness of the faces tested. The traditional cross-race effect, in which own-race faces are recognized more accurately than other-race faces, may be evident only for faces which fall in the mid-range of distinctiveness. The cross-race effect changes as the faces reach the extremes of the distinctiveness distributions. As demonstrated in the current study, faces that are very distinctive reverse the cross-race effect such that other-race faces are recognized more accurately than own-race faces. This reversal is due to the relative amount of competing faces surrounding own- and other-race distinctive faces. Conversely, very typical faces tend to be typical not only of their own race, but for all faces in the world. Thus, these faces are recognized with equal accuracy regardless of race. As the current study is the first to report this phenomenon, future research is necessary to explore it in more detail. An examination of recognition accuracy for the full range of distinctive faces in more than one race would be the next logical step to follow up these results.

The incidental learning condition was predicted to elicit better recognition accuracy, at least for the five-year-old children and adults. However, performance in the incidental and intentional learning conditions were overall very similar to each other. When differences were found (i.e., in the percent correct and hit rate measures), participants in the intentional learning condition were actually more accurate than participants in the incidental learning condition. Previous research has shown this effect (i.e., intentional learning leading to more accurate recall than incidental learning) with novices and the reverse for experts. For instance, Norman et al. (1989) found that novices more accurately recalled medical information when presented in an intentional learning condition, while experts more accurately recalled medical information when presented in an incidental learning condition. Face recognition research has typically portrayed adults as "experts" in face recognition, and thus the incidental learning condition should have elicited better recognition than the intentional learning condition. Follow-up studies need to be conducted to explore the issue of intentionality to a greater degree. The current study manipulated only the task instructions to allow comparison across conditions. Perhaps greater differences in the methodologies are needed to obtain the predicted results. For instance, if the intentional learning condition simply presented participants with a series of faces (i.e., without the story context) and emphasized memorization instructions (as is done in most of the previous face recognition studies), differential effects may be found.

The results of the current study represent new advancements in the research on the cross-race and distinctiveness effects. The unique research design seems to elicit different levels of face recognition skills than has been found in other designs. For instance, previous research suggested that the distinctiveness effect did not emerge until at least seven years of age and even then it was not adult-like; however, the distinctiveness effect was found very clearly and strongly at all ages (i.e., five years through adulthood) in the current study. In addition, the Race x Distinctiveness interaction revealed a more complex role of race in face recognition than was previously thought. Recognition of very typical faces is not affected by race of face, but an other-race bias exists for very distinctive faces. The unique storybook format and manipulation of intentionality during the learning phase represent exciting new possibilities in research design that should be further tested in future studies.

2.3.1. Remaining issues

The previous review of the face recognition literature identified several issues related to discrepancies in the developmental face recognition research. The current study serves as a first step towards addressing the issues that were applicable to this investigation. For instance, problems with the particular stimuli used in previous studies included distractions of hair and clothing cues. Children have difficulty ignoring irrelevant cues such as clothing (Friere & Lee, 2001) and hair is a salient cue that even newborns can use to recognize faces (Pascalis et al., 1995). The current study utilized pictures of faces with both the hair and clothing cues occluded. Participants in the current study were unable to use these cues to identify the faces. In order to make these pictures seem more naturalistic, the participants were informed that they were seeing the individuals through a peephole in a door. While future research needs to be conducted to confirm the identified stimulus issues, the current study took previous research into account when trying to control for extraneous factors.

Another methodological issue raised by the previous review was the relative demands of implicit and explicit tasks. Research with infants employs implicit tasks by necessity whereas most research with children and adults utilize explicit tasks. Incidental learning conditions result in better recognition performance for young children (e.g., Istomina, 1975; Newman, 1990) and experts (Norman et al., 1989). In addition, face recognition is a skill that is automatic and unconscious under most circumstances. Therefore, it seems reasonable to suggest that perhaps face recognition is a skill that needs to be studied under incidental learning conditions. The current study compared incidental and intentional learning conditions to determine whether the predicted differences in recognition performance were found. Although the current study did not find much evidence of differences between the incidental and intentional learning conditions, future research needs to address this issue in different ways to explore potential differences between incidental and intentional learning tasks. In the current study, both the incidental and intentional learning task were encompassed in a storybook format. Perhaps this format made the intentional task more similar to an incidental task. Perhaps if a third condition were added, in which the faces were presented without the context of a story, the predicted differences between it and the incidental design may have been strong.

Finally, the previous review of the existing literature questioned whether the developmental course of face recognition skills is a linear one. A U-shaped curve or simply development at a slower pace during early childhood may account for the discrepancies between the infant and child literatures. As suggested earlier, future research needs to investigate the development of skills at multiple ages, with special attention to the under-studied preschool population. The current study included older preschool-aged children and has begun to investigate the development of the cross-race effect at multiple time points in development. Future research also needs to include the development of face recognition skills across the preschool years to map the developmental course in this important period. Similarly, the cross-race effect has not been investigated in much detail during childhood, and there are many questions that remain unanswered. The current study did not find evidence of any developmental differences in the cross-race effect between five years and adulthood, and face recognition performance overall was found to increase linearly across the age groups. Future research, however, stills needs to investigate these skills at younger ages to determine whether the developmental course is truly linear from infancy through adulthood.

2.3.2. Future research

2.3.2.1. Cross-race effect. The results from current study identified some questions about the cross-race effect that remain unanswered. Previous research has addressed the role of distinctiveness in the cross-race effect and found that distinctiveness affects recognition of own- and other-race faces. Thus, the individual's own-race typicality distributions are sufficient for the encoding of other-race faces to display some recognition advantage for other-race faces, or individuals have had sufficient experience with other-race faces to encode them according to their own typicality distributions. The current study extended these findings to recognition of extremely distinctive and typical own- and other-race faces. While previous studies have investigated recognition with faces along a range of distinctive values, the current study used only those faces at the extremes of the distribution. As such, it was discovered that these faces reveal a different picture concerning the cross-race effect. The extremely typical own- and other-race faces are recognized equally well, while the extremely distinctive other-race faces are recognized more accurately than the extremely distinctive own-race faces. Thus, when faces are very typical, race appears to be irrelevant. However, when faces are very distinctive, the cross-race effect appears to reverse. According to Valentine's face space framework theory, faces in less densely populated regions are recognized most accurately. If other-race faces are stored according to a typicality distribution, then very distinctive other-race faces should be stored in the least populated region of face space. Future research needs to be conducted to confirm these findings. The whole range of distinctiveness for own- and other-race faces should be compared in a single study in order to replicate previous cross-race effects and the current study's finding of an advantage for other-races faces when very distinctive.

In addition, the current study actively compared recognition performance under incidental and intentional learning conditions with the expectation that incidental learning should result in increased recognition accuracy for at least the five-year-old children and the adults. However, only slight differences were found between the two conditions. The procedural differences between the incidental and intentional learning conditions were embedded in a naturalistic story and may have been too subtle for the participants. The only difference was the type of information provided in the instructions prior to the task. Future studies may need to exaggerate these differences to truly determine whether intentionality affects face recognition performance. Also, it is difficult to determine whether participants in the intentional learning condition were actively attempting to memorize the faces, or whether they were too involved in the story to evoke learning strategies. Perhaps the storyline distracted the participants from the main task of memorization. Future studies need to examine the degree of strategy use in each condition to ensure that the instructions are evoking different learning strategies.

2.3.2.2. Face perception and recognition skills. A number of issues with the developmental face perception and recognition literature have been raised in this paper. Each of the identified issues suggests the possibility of new lines of research. Although only one of these lines was pursued in the current study, the reviews of the existing literature and Table 2 highlight several gaps that future research can address.

For instance, the research on the development of the cross-race effect has been very sparse thus far. Although the current study attempted to address the questions that this literature has failed to answer, future research is needed to explore the development of this skill more fully. In addition, the development of the caricature effect has only been examined in middle to late childhood. Also, the research on the preference for attractive faces has only been investigated in infancy and adulthood. Very little is known about the developmental course of this preference and it should be investigated in the future. Future research needs to continue to investigate these skills across the developmental span. However, it is not only important that researchers fill in the gaps in the literature. There are theoretical gaps in the research that need to

Table 2: Summary of current research literature

	NEWBORNS	INFANTS	TODDLERS & PRESCHOOLERS	CHILDREN	ADULTS
PROTOTYPE FORMATION	NOT YET DEVELOPED	As early as 3 months, with a series of 4 faces	Able to form prototypes, but false alarm rate increases from 3-6 years	NOT YET STUDIED	Able to form prototype from a series of _ faces, high false alarm rates to prototype
RECOGNITION OF FAMILIAR & UNFAMILIAR FACES	Recognition of familiar face within hours of birth, with external cues present	Recognition of unfamiliar face by 1 month for short time, recognition after 2 week delay by 6 months	Able to remember unfamiliar faces for a short time, limited by the number of faces recalled (only 1 face for 3-year olds)	Recognition of unfamiliar faces at adult-level by 10 years	Recognition of 100's of faces over very long period of ime (30+ years)
PREFERENCE FOR ATTRACTIVE FACES	Preference is present, may be supported by different mechanism	Evidence of preference by 6 months, affects social interactions by 12 months	NOT YET STUDIED	NOT YET STUDIED	Consistent agreement among adults in attractiveness ratings
CONFIGURAL PROCESSING	NOT YET STUDIED	Evidence of advantage for upright vs. inverted faces by 7 months	Children 2-5 years employ analytic processing when given choice, able to process configurally but not efficient	Children 6-11 years process configurally, still becoming more efficient throughout childhood	Process faces in a configural manner
CATEGORIZATION OF GENDER	NOT YET STUDIED	Categorization of most typical faces by 6 months	Categorization of all faces, not yet at adult accuracy level	NOT YET STUDIED	100% categorization of most faces, faster reaction times for typical vs. less typical faces
DISTINCTIVENESS EFFECT	NOT YET STUDIED	NOT DEVELOPED BY 10 MONTHS	Preliminary data suggests recognition advantage for 3-4 year olds	Recognition advantage for 5-13-year olds (reaction time), 7-13-year olds (accuracy)	Recognition advantage for distinctive vs. typical faces
CROSS-RACE EFFECT	NOT YET STUDIED	Recognition advantage at 3 months when single own-race and single other-race face is compared	NOT YET STUDIED	Recognition advantage developed by 5th grade, gains strength through 8th grade	Recognition advantage for same-race vs. other-race faces
RECOGNITION OF CARICATURES	NOT YET STUDIED	NOT YET STUDIED	NOT YET STUDIED	Categorization and recognition advantage by 6-10-year olds	Ability to recognize caricatures as well as their veridical depiction

be addressed as well. At this time very few researchers are thinking about the development of face expertise in terms of advanced knowledge of feature distributions, advanced processing strategies, and the interaction of expert knowledge and processing strategies.

The discrepancies between the infancy and child research that have been discussed above represent important issues that future research can resolve. The underlying reason for these discrepancies has yet to be determined. Several lines of research could be undertaken to shed light on these causes. For instance, there are not enough studies being conducted with preschool-aged children. More investigations with this population could help to clarify the developmental course of face expertise, identifying how it develops between infancy and childhood. These studies should be designed especially to address the possible variations in the developmental course of face expertise, specifically a U-shaped curve in development or slowed development during the toddler and preschool years.

Future investigations also need to allow for more accurate comparisons between the infancy and childhood literatures. Better control over stimulus issues and more similar tasks might highlight continuities across development. Similar to Keen (2003), future studies need to compare face recognition performance of infants and children within the same paradigm. Only then can the developmental course of face recognition skills be definitively determined.

In addition, the processes underlying face perception and recognition skills are of considerable interest to researchers (e.g., Cashon & Cohen, 2004; Schwarzer, 2000, 2002; Tanaka & Sengco, 1997; Thompson et al., 2001). However, essentially all of the research conducted on face processing has compared featural and configural processing. Many of the studies suggest that infants and young children are processing faces in a more featural manner, whereas older children and adults process faces in a more configural manner. The difference in processing strategies between infants and children may explain the discrepancies found when comparing these literatures. On the other hand, there may be additional developmental processing differences that have not yet been explored by researchers. Future research should consider other aspects of face processing and how they change throughout development such as the role of distinctiveness of individual features and a potential weighting system in attention.

In addition, future research needs to be conducted to explore the role of incidental versus intentional learning conditions to determine whether differences in performance can be attributed to this task difference. Although no differences were found between incidental and intentional conditions in the current study, the differences between these conditions were very minimal. Future studies should exaggerate the differences between conditions to ensure that the learning strategies of the two groups are different. In addition, the differences between incidental and intentional learning should be investigated in all areas of face recognition research. Perhaps other paradigms, such as implicit memory tasks (i.e., probing memory without awareness) would be influenced by differences in learning conditions. In addition, the current paradigm needs to be compared to more traditional paradigms that do not incorporate any storybook format to examine the role of intentionality more clearly. Research such as this should help to determine whether the discrepant results identified in the developmental face literature could be accounted for by differences in the intentionality of task demands.

Finally, several interesting questions have been raised in this paper about the development of processing skills, the core knowledge base of faces, and the potential interaction between these two. Future research should be designed to address whether these two factors interact during development and the precise nature of their interaction. Although potential research ideas have been posited in this paper, many others could be formulated. For instance, a simple investigation of the areas of faces that are used in face recognition and how they change through development might highlight the interaction of processing styles and a developing knowledge base.

Research on face recognition is an important area of study and is currently an active area of exploration for many researchers. This research has made important strides in our understanding not only of how individuals process faces, but also how individuals form categories, develop expertise, and attend to typicality. Undoubtedly, the area of face recognition research is very large and difficult to integrate. The current review and investigation has made valuable progress towards these goals. Furthermore, this paper has highlighted several lines of future research that would further advance our understanding of face perception and recognition skills. Together, these future research areas would clarify the development of face expertise and consolidate the findings into a single theoretical model.

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