

Predicting Face Recognition Skills in Children: Global Processing and Attention to the  
Eyes

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## Dedication

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## **Abstract**

Faces are, arguably, the most important stimulus in our lives. Yet, we understand very little about what information is used to recognize faces. Two theories exist in the literature on this topic. First, it is widely believed that successful face recognition depends on the ability to utilize configural, or holistic, information about the face. Second, many have speculated that attention to the eye region of the face is essential for successful face recognition. However, few studies, none with children, have directly evaluated this relationship by examining individual differences in face processing. Thus, the goal of the following studies was to examine how individual differences in face recognition skills are predicted by configural processing of the face and, in particular, attention to the eye region. Across four experiments, children completed face recognition tasks using an eye tracker, tasks of configural processing, and an object recognition task. Results from Experiments 1 and 2 support the notion that attention to the eye region and configural processing of faces as measured by the Part-Whole Task are predictive of face recognition scores as measured by the Cambridge Face Memory Task for Children. Furthermore, these experiments provide preliminary evidence that attention to the outer areas of the face, such as the forehead, may inhibit face recognition ability. Experiment 3 generally replicated these findings, with a few exceptions, by examining a pre-selected group of children and subsequently comparing high and low performers on the Cambridge Face Memory Task. Finally, Experiment 4 examined six children with developmental prosopagnosia. Results from this experiment suggest that children with prosopagnosia are a very heterogeneous group. The results of these studies generally

support three hypotheses: 1. Children who demonstrate greater attention to the eye region perform better on tasks of face recognition, 2. Higher scores on tests of configural face processing predict higher scores on tasks of face recognition, and 3. Children who demonstrate a greater degree of configural face processing are more likely to attend to the eye region of the face (Experiment 2).

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## CHAPTER 1: Introduction

### General Introduction

*‘Good-bye, till we meet again!’ she said as cheerfully as she could.*

*‘I shouldn’t know you again if we did meet,’ Humpty Dumpty replied in a discontented tone, giving her one of his fingers to shake: ‘you’re so exactly like other people.’*

*‘The face is what one goes by, generally,’ Alice remarked in a thoughtful tone.*

*‘That’s just what I complain of,’ said Humpty Dumpty. ‘Your face is the same as everybody else has—the two eyes, so—’ (marking their places in the air with his thumb) ‘nose in the middle, mouth under. It’s always the same. Now if you had the two eyes on the same side of the nose, for instance— or the mouth at the top—that would be some help.’*

*‘It wouldn’t look nice,’ Alice objected.*

*-Lewis Carroll, Through the Looking Glass (Carroll, 2011, p. 245).*

Faces are the most distinctive cue to a person’s identity (Bruce & Young, 1986) and, arguably, the most important stimulus in our lives (Goldstein, 1983). Very early in life, we use faces to recognize our caregivers who provide us safety, nourishment, and knowledge about the world. As we age, we increasingly use faces to identify others for the purposes of finding a partner, building our career, and maintaining social relationships. Thus, face recognition is important for both survival and status within the social world, beginning early in life.

Lewis Carroll’s description of Humpty Dumpty’s interactions with Alice in his book, *Through the Looking Glass*, highlights the importance of face recognition for social interaction. Without the ability to distinguish Alice’s face from another, Humpty Dumpty is unable to differentiate Alice from other human-like characters. His description of faces is very similar to the description of faces offered by many with developmental prosopagnosia (DP), a disorder that disrupts one’s ability to process faces. These individuals, like Humpty, have little difficulty identifying the presence of a face or

location of face parts, such as the eyes, nose, and mouth. Rather, the ability to distinguish between or recognize particular faces is absent (Duchaine & Nakayama, 2006), leaving them with the same paradox as Humpty Dumpty—unable to recognize a familiar person upon second encounter.

The goal of this thesis is to investigate the processes involved in face recognition—a skill that comes easily to most—that Humpty Dumpty is seemingly incapable of. Thus, the aim of the present work is to examine what aspects of faces (e.g. the eyes, global structure, etcetera) are most important for successful face recognition. Previous work has demonstrated that there are vast individual differences in face recognition skill (Russell, Duchaine, & Nakayama, 2009). It is, therefore, possible that some individuals process face information in a more selective and efficient way than others in terms of the facial information that is used or extracted from the face. Understanding the relationship between this process and face recognition skill is important for evaluating how individual differences may contribute to face recognition skills and subsequent social functioning, as will be outlined in the following sections.

### **Why Do We Need To Understand Face Recognition? The Case Of Prosopagnosia.**

The importance of face recognition has been highlighted by work investigating cases of prosopagnosia. Prosopagnosia, generally, refers to an inability to recognize faces despite intact early visual processing and an absence of generalized cognitive dysfunction (Duchaine & Nakayama, 2006). Two forms of prosopagnosia have been identified. The first, described in Bodamer's initial report (Bodamer, 1947; Ellis & Florence, 1990) is of acquired prosopagnosia, or an inability to recognize faces as a result

of traumatic brain injury. In these cases, an individual experiences typical capabilities in face recognition until a brain injury severely interrupts their ability to identify others. Developmental prosopagnosia<sup>1</sup>, on the other hand, is characterized by an inability to recognize faces despite no history of brain damage and intact early visual processing and intellectual function (Behrmann & Avidan, 2005; Duchaine & Nakayama, 2006; Kress & Daum, 2003). DP is particularly interesting because the causes are yet unknown and the effects of the disorder can be just as severe as that seen in acquired prosopagnosia (Duchaine & Nakayama, 2006).

Prosopagnosia, as well as other forms of agnosia, has been classified into two forms: apperceptive and associative. The apperceptive form of the disorder arises from perceptual impairments documented by an inability to judge two faces as the same or different when presented simultaneously. The associative form exists in cases that can distinguish between faces but cannot recognize them later (Behrmann & Avidan, 2005; Joy & Brunsdon, 2002; Lissauer, 1980). The associative type has also been referred to as prosopamnesia (Wilson, Palermo, Schmalzl, & Brock, 2010).

Although both acquired and developmental prosopagnosia are relevant to this thesis, the population of those with DP are much greater in number and often experience earlier onset of the disorder. For these reasons, the goal of the present thesis—to better

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<sup>1</sup> In the literature, there are discrepancies regarding the definition and proper terms for a face recognition deficit without evident brain injury. For example, Behrmann and Avidan (2005) have argued that “developmental prosopagnosia” has occasionally been used to describe cases of childhood- or infant-onset prosopagnosia resulting from visual deprivation or brain injury occurring early in life. Thus, they use the term “congenital prosopagnosia” to refer to cases of face blindness in which there is no attributable cause for brain damage evident prenatally or after birth. Kennerknecht et al. (2006), on the other hand, argue that both congenital and developmental prosopagnosia could be acquired and thus refer to non-acquired cases as “hereditary prosopagnosia.” Because it is difficult to prove that face recognition difficulties were present at birth, this thesis uses the more general term “developmental prosopagnosia” to refer to cases of prosopagnosia present early in life without identifiable brain injury.

understand the processes underlying successful face recognition in children—is most relevant to cases of DP. Therefore, the following discussion will mainly highlight DP, rather than acquired prosopagnosia, except where relevant.

### **Prevalence of Developmental Prosopagnosia**

It used to be believed that prosopagnosia (both the acquired and developmental forms) were quite rare. However, recent reports examining the prevalence rates of DP suggest that the disorder may affect many more people than was once believed.

In the first prevalence report of DP, Kennerknecht et al. (2006) evaluated the face recognition skills, based on self-report and semi-structured interviews, of 687 non-selected individuals and found that more than 2% of the population in question experienced severe face recognition difficulties that interfered with their daily lives. They subsequently replicated this finding in a sample of 533 non-selected Chinese adults from Hong Kong (Kennerknecht, Ho, & Wong, 2008). These initial studies provided the first evidence that DP may be much more prevalent than was once believed.

However, the findings of these reports are somewhat limited because they rely on self-report measures and semi-structured interviews rather than behavioral methods. To address this issue, Bowles et al. (2009) examined a population of adults in Australia and Israel using behavioral methods rather than self-report. They evaluated nearly 300 non-selected adults using the Cambridge Face Memory Task (CFMT; Duchaine & Nakayama, 2006) and found that more than 2% of their sample scored more than 2 standard deviations below the mean and reported difficulties in recognizing faces that interfered with their daily lives. Although this percentage could reflect an artifact of a normal

distribution (2% should naturally fall 2 standard deviations below the mean), the individuals in this range reported significant difficulty in recognizing faces in their everyday lives (Bowles et al., 2009). In addition, Duchaine (2008) reported high prevalence rates based on the behavioral data collected in his labs and the frequency by which he has been contacted by self-diagnosed adults.

Although prevalence studies have not been completed with childhood populations, adults' reports that their DP was present in childhood provides initial evidence that DP is likely an early onset disorder (Duchaine & Nakayama, 2006). Therefore, the implications that arise from these high prevalence rates are applicable for children as well. Overall, these results highlight the practical implications of establishing a better understanding of face recognition and how this process may be impaired for some individuals.

### **Symptomology and Social Consequences of Developmental Prosopagnosia**

The high prevalence rates documented by the several different labs mentioned above highlights the importance of establishing a list of characteristics of DP that can be used for identification of cases. This may be especially important for children who, if identified early enough, may benefit from interventions tailored to their needs.

The main characteristic of DP is an inability to recognize faces that should be familiar. Children and adults with DP will often make mistakes in recognizing others, especially when out of their typical context. For example, a child may have little difficulty recognizing their teacher when in the classroom because they are likely the

only adult present. However, this same child may fail to recognize their teacher during a chance encounter at the grocery store.

Furthermore, individuals with DP often rely on non-facial cues to recognize others such as hairstyle, gait, voice, and context (Behrmann & Avidan, 2005; Duchaine & Nakayama, 2006; Kress & Daum, 2003; Yardley, McDermott, Pisarski, Duchaine, & Nakayama, 2008). Although these cues can be helpful for recognition, many of them, such as hairstyle, are temporary and unreliable. Also cues such as voice and gait can only be used if the person in question is speaking or moving. As a result, individuals with DP will make frequent mistakes in recognition.

In addition, there are many other ramifications of DP, most of which are social in nature. To date, only two investigations of DP have directly examined the psychosocial consequences of the disorder. The first, Yardley et al. (2008), interviewed 25 adults with DP to examine the effect that the disorder had on their everyday lives. As a result of their inability to recognize others, participants reported feelings of embarrassment, guilt, and failure. Furthermore, they indicated a certain degree of fear and avoidance of social situations. In extreme cases, chronic anxiety led to long-term social isolation, limited employment opportunities, and loss of self-confidence. These adults also experienced difficulty in telling others about prosopagnosia (due to general lack of awareness) and hesitancy to do so. Thus, they were dependent on others in social contexts and, eventually, became introverted and lacked self-esteem. Thus, for obvious reasons, DP could have a lasting effect on the formation and maintenance of social relationships.



The second study evaluating the psychosocial consequences of DP examined the disorder from the perspective of a child (Diaz, 2008). Steve, a 13-year-old male, experienced severe prosopagnosia, as well as deficits in object recognition and memory (e.g. multi-step instructions). He depended on non-facial visual cues to identify others, such as clothing and hairstyle. Via semi-structured interviews, Steve reported concerns in three categories: academics, social interactions, and safety. Academically, Steve experienced limitations in courses such as drama, where he could not tell the characters apart, making it difficult for him to participate. Socially, Steve reported being labeled aloof and unfriendly—ostracized by his peers. Because of this, he was unable to expand his social circle and maintain friendships past a first encounter. Finally, Steve reported concerns about getting lost in crowded social situations (e.g. malls and fire drills). In particular, he experienced great difficulty transitioning to middle-school where the number of students and teachers he encountered on a daily basis increased dramatically. Diaz concluded that “children with prosopagnosia rarely have a wide circle of friends because friendships are difficult to develop and keep” (Diaz, 2008, p. 285). This case evaluation sheds light on the possible long-term consequences of social isolation resulting from DP in childhood.

### **Why study Face Recognition?**

There are several reasons for studying face recognition in both adults and children. The first, and most obvious, reason is to try to better understand DP so that the consequences of this disorder can be alleviated in those that are suffering in a social

domain. By examining DP early in life, we may be able to alleviate some of the long-term social issues associated with the disorder before they become too severe.

Second, many adults with face recognition difficulties (and presumably most children with face recognition difficulties) are unaware of their inability to recognize faces. Because people do not frequently talk about face recognition, and thus, there is no obvious comparison, individuals can age well into adulthood without realizing that DP is the cause of their social difficulties (Behrmann & Avidan, 2005; Duchaine & Nakayama, 2006). This is evidenced by examinations of un-selected populations of people who do not spontaneously report face recognition difficulties but subsequently perform very poorly on face recognition tests such as the CFMT (Bowles et al., 2009). These individuals are likely unaware of their face recognition problem because they have been able to rely on other cues to identify others such as hairstyle, clothing, characteristic features, voice, and context (Behrmann & Avidan, 2005; Duchaine & Nakayama, 2006; Kress & Daum, 2003; Yardley et al., 2008). Therefore, research focusing on the developmental trajectory of face recognition may uncover ways to identify the disorder early in life. More specifically, by investigating cases of childhood DP, we can evaluate how early the disorder can be detected against a backdrop of typically developing face recognition skills and attempt to differentiate DP from other disorders such as Autism (Joy & Brunsdon, 2002).

There are additional reasons for investigating face recognition in childhood populations. By some definitions (e.g. Behrmann & Avidan, 2005), developmental prosopagnosia is a disorder that begins early in life. In fact, many adults with DP report

that their face recognition difficulties have been present since childhood (Duchaine & Nakayama, 2006). Likewise, studies of DP often operate on the assumption that the face recognition impairment under question has always been present, suggesting that the deficit should be present in early childhood (Wilson et al., 2010). However, very few cases of DP have been presented in the literature—to date, only 6 experimental studies of DP in children have been reported (Wilson et al., 2010). Consequently, to understand the causes and trajectory of the disorder, childhood cases should be evaluated. Childhood is a time in which early social experiences lay the foundation for later social development. Thus, missing critical social experience early in life, as a result of DP, could interfere with the development of important social skills needed later in life.

Furthermore, studying the early face recognition skills of children may have important implications for training programs. Several attempts have been made to train the face recognition skills of adults with DP. Although some of these programs have been effective (e.g. DeGutis, Bentin, Robertson, & D'Esposito, 2007; DeGutis, DeNicola, Zink, McGlinchey, & Milberg, 2011), none of them have demonstrated long-lasting effects that generalized to new faces. By better understanding face recognition in childhood, we may be able to attempt training programs earlier in life, when the neural system is more plastic and more likely to benefit from training on a long-term basis.

Finally, studying the *development* of the disorder can inform theories of face recognition (Duchaine & Nakayama, 2006), how face recognition works, and the developmental trajectory for normal face recognition.

## Theories of Face Recognition

Developmental prosopagnosia provides a case for understanding face recognition in typically developing populations so that we can better evaluate what aspects of this process are impaired in those who are unable to recognize familiar faces. The central question of this dissertation is “what information provided by the face is most important for face recognition?” Regardless of the causes of DP—whether they be experiential, neurological, genetic, or a combination of the three – a better understanding of how children use face information could be informative for both identifying cases of DP and providing successful intervention programs.

In this domain, researchers have been thinking about how the face recognition system works for years, with many models stemming from the Bruce and Young (1986) model of face recognition. However, less work has directly examined *how* faces are recognized in terms of what information in the face is most relevant for face processing. What information provided by the face (e.g. the eyes, the overall face structure, etcetera) is most important for face recognition? How is that information used? And what happens if that information is not attended to? In order to best understand, identify, and treat DP, we need to know what aspects of the face are most important for face recognition. Are those who are poorer at face recognition not sensitive to this information? There are two main theories about what information is most important for face recognition, both of which may be relevant to understanding prosopagnosia.

## **Configural Face Processing**

One of the more popular theories of how typical adults and children are able to recognize faces is that we utilize configural information provided by the overall structure of the face. Several terms have been used to describe this information. For example, holistic processing has been used to refer to “relatively less part decomposition [of the face] than other types of objects” (Farah, Wilson, Drain, & Tanaka, 1998, p. 482). In other words, holistic processing does not rely on recognizing each individual face part in a piecemeal fashion (i.e. the eyes, nose, and mouth) but rather focuses on the face as whole, a more gestalt approach. Another term, relational processing, is based on the spatial relationships between the parts of the face and also the location of the face parts in relation to a template or prototype (Diamond & Carey, 1986). Thus, more than holistic processing, the relational processing approach puts emphasis on the local features (or parts) of the face, but only via their spatial relationships.

More generally, global or configural processing was described by McKone, Kanwisher, and Duchaine (2007, p. glossary):

*... in comparison to objects, processing for faces involves (i) a stronger and mandatory perceptual integration across the whole (in one theory, the mechanism does not decompose faces into smaller parts; Tanaka & Farah, 1993) and (ii) a more precise representation of the ‘second-order’ deviations from the basic (‘first-order’) shape, including precise spatial-relational information (e.g. distance from corner of left eye to tip of nose) and precise feature shape (Yovel &*

*Kanwisher, 2005). This computational style is referred to as holistic or configural processing (terminology differs among researchers) . . .*

The distinction between these terms and their definitions is somewhat of a moot point for the purposes of this thesis.<sup>2</sup> Rather, the important point is that these theories posit that face recognition uses configural information rather than only piecemeal or entirely feature-based information for recognition. Since the experimental paradigms used in this thesis do not compare holistic versus relational processing, the focus is instead on characterizing the strength of the relationship between configural processing, more generally, and face recognition ability.

Several lines of research have substantiated the connection between configural processing and face recognition skill. The most well-known is via the inversion effect (Yin, 1969)—a term used to describe the phenomena that faces are more easily recognizable when presented upright than when inverted (Leder & Bruce, 2000). The inversion effect has been clearly demonstrated in both adults and children (see Valentine, 1988 for a review of literature on the inversion effect). It is assumed that the *configuration* of the features of an upright face is what is important for recognition. If the features alone, rather than their configuration, were most important for face recognition, it should be just as easy to identify both upright and inverted faces, but this is not the case. Indeed, groups have demonstrated that inversion has very little effect on the perception of local features whereas faces that differ in configural information are affected by inversion (Leder & Bruce, 2000). However, see Sekuler, Gaspar, Gold, and

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<sup>2</sup> For the purposes of this paper, the term “configural processing” will be used to represent any type of configural processing including “holistic” and “relational.” However, when citing others’ work, the term they used in their original publication will be used.

Bennett (2004) for a description of how the inversion effect may be better explained by quantitative, rather than qualitative, differences in processing between upright and inverted faces.

In addition, holistic processing of faces is demonstrated by studies showing a global effect using the Composite Face Task and the Part-Whole Task. The composite face effect (see Figure 1) is shown when the top of one face is presented aligned or misaligned with the bottom half of a different face. In this task, it is difficult to recognize the identity of the top half of a face if it is aligned with the bottom half of a different face, suggesting that the whole face is taken into account in face recognition (Young, Hellawell, & Hay, 1987).

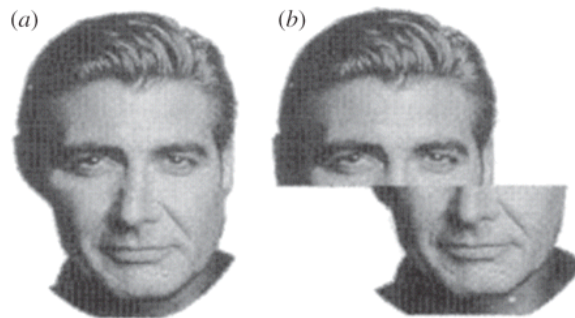


Figure 1. The Composite Face Task. In this task, the top half of one face is presented with the bottom half of another face. The top half (George Clooney) is easier to recognize when it is misaligned than when it is aligned with the bottom half (Harrison Ford). This is known as the composite face effect. Image reprinted with permissions from Parr (2011) by permission of the Royal Society.

Similarly, the Part-Whole Task (Tanaka & Farah, 1993) presents the participant with a target face that they are asked to learn. Then, they are later asked to identify one feature of the target face from a lineup. The feature is either presented in isolation or in

the context of the face (see Figure 2). For example, they might be asked to identify the target's nose from a lineup of two noses or identify the target's face from a line up of two faces, all of which are identical with the exception of the noses. In other words, the part and whole-face versions of the task are identical with the exception of the presence of the rest of the face and the question asked. In this task, participants are better able to pick the correct feature within the context of the entire face than when the features are presented in isolation.

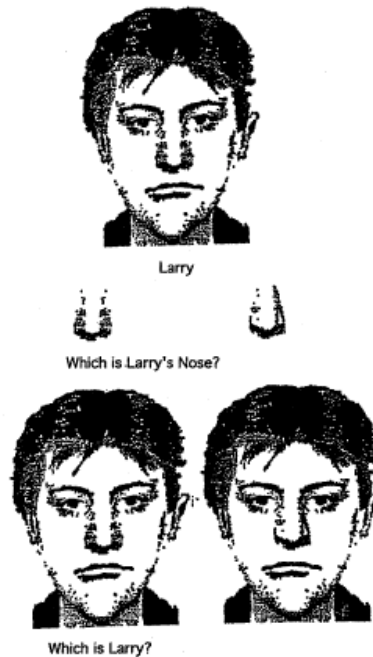


Figure 2. The Part-Whole Task. In this task, participants are asked to learn a target face (e.g. Larry) and then are presented with either a part or a whole trial. On part trials, only one portion of the target face is presented (e.g. the nose) next to the same part of a different face. On whole trials, the two faces presented are identical with the exception of one feature (e.g. the nose), one of which matches the target face and one of which matches another face. Better performance on whole trials is presumed to reflect a holistic advantage in face processing. Image reprinted with permissions from Taylor & Francis from Tanaka, Kay, Grinell, Stansfield, and Szechter (1998).



In addition to these methodological demonstrations of configural processing, there are several other lines of behavioral evidence suggesting that configural processing of faces is important for successful face recognition. First of all, although the findings are mixed (Cassia, Picozzi, Kuefner, Bricolo, & Turati, 2008; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007), some reports indicate that children, who may have poorer face recognition abilities than adults, show smaller global processing effects (e.g. Pellicano & Rhodes, 2003) suggesting that face recognition is improving with global processing.

Second, in the adult literature, there has been discussion about the possibility that those with DP may have a deficit in configural processing of faces. By this hypothesis, the individual is unable to perceive the face as a whole and rather perceives the face in a more piece-meal type fashion (Levine & Calvanio, 1989). This would explain why at least some with DP are able to complete face discrimination or matching tasks rather easily, because they can do a feature-by-feature comparison (Kress & Daum, 2003). This question has been less examined in children. However, studies using the Part-Whole Task in which it is easier to identify a feature of the face within the whole-face context than in isolation suggest that holistic-like processing of faces is present even by age 6 (Tanaka et al., 1998). Therefore, deficits in face processing early in life may reflect a failure to develop this specialized skill. Indeed, adults with DP often do not show evidence of holistic processing of faces. For example, several reports have suggested that those with prosopagnosia do not show an inversion effect typically seen in adults (Avidan, Tanzer, & Behrmann, 2011; Farah, Wilson, Drain, & Tanaka, 1995). Similarly,

in studies comparing DP adults with controls, those with DP occasionally show smaller composite effects (Avidan et al., 2011; Palermo et al., 2011). Furthermore, Avidan et al. (2011) found that the degree of composite effect (or lack thereof) correlated with face recognition skill as measured by diagnostic measures, providing convincing evidence that holistic processing of faces is predictive of individual differences in face recognition, at least for those with prosopagnosia. Likewise, Farah, Tanaka, and Drain tested an adult with DP and did not find evidence of a part-whole effect. Rather, their performance on the part and the whole tasks were the same (unpublished data described in Farah, 1996). Finally, several groups have shown that perception of relational information of the face, such as the distance between the eyes, is impaired in cases of prosopagnosia. For example, Ramon and Rossion (2010) found that an adult with acquired prosopagnosia was impaired at judging the relative distances between features. Similarly, DeGutis and colleagues (DeGutis et al., 2007; DeGutis et al., 2011) found that training adults with DP to attend to the relational information of the face improved face recognition abilities. However, it may not be the case that all individuals with DP have holistic processing impairments (Bukach, Bub, Gauthier, & Tarr, 2006; Susilo et al., 2010).

However, until recently, the relationship between configural face processing and face recognition had not been tested directly. Yet, training programs such as those by DeGutis and colleagues operate on the assumption that those with poor face recognition skills have a deficit in global processing. Thus, directly examining this relationship is essential.

To address this question, several recent studies have examined this relationship in adults. Konar, Bennett, and Sekuler (2010) examined the correlation between a partial version of the composite face task and face recognition skills as measured by a face identification task. They found no correlation between global processing and performance on this task. However, there were several critical problems with this study. First, the statistical method they chose to measure global processing (subtracting the score of aligned trials from misaligned trials) is flawed. As Wilmer, Garrido, and Herzmann (2012) point out, this type of analysis may misrepresent data. Rather, to best represent the global processing abilities of these participants, it is better to regress out the control variable, thus isolating performance related to configural face processing by examining the residuals unexplained by part-trials. Second, the face identification task used in this study is less than ideal—the faces included local features such as hair and the target face and test faces were presented simultaneously in Experiment 1, increasing the likelihood that a matching process could be used to complete the task (however, in Experiment 2, this was adjusted). Both of these limitations increase the possibility that participants would use more local cues than global cues to select the correct face. To address this issue, it may have been better to use a more established test of face recognition. For example, the Cambridge Face Memory Task (Duchaine & Nakayama, 2006; see figure 4) does not provide local cues for recognition and has been validated and replicated across many labs and groups of participants (both typically developing and DP).

Thus, in response to this study, Richler, Cheung, and Gauthier (2011) used the Cambridge Face Memory Task and the complete composite face task to address the same question. Using this method, they found a significant correlation between global face processing skills and face recognition. Although they too used a subtraction method, rather than regression method, to measure global processing, their findings nonetheless lend support to the hypothesis that those who process faces globally are better at face recognition.

Subsequently, Wang, Li, Fang, Tian, and Liu (2012) reported concerns about comparing difference scores on the composite face task with an absolute measure of face recognition. To address this issue, their participants completed a face recognition task (old/new) and flower recognition task (so that object recognition could be subtracted out of face recognition performance). In addition, they completed the composite face task and the part-whole task. They found that correlations between the global processing tasks were significantly correlated with face recognition. In addition, they compared performance between individuals with face recognition scores 1 SD below the mean and 1 SD above the mean and found that global processing of faces differed between these two groups. However, this study also suffers from the statistical limitations mentioned by Wilmer et al. (2012). Also, this study, like Konar et al. (2010), uses a face recognition test that has identical photographs between the learning and test phase which may limit the use of global processing strategies and may explain the rather small effect sizes.

Finally, a recent study by DeGutis and colleagues (2013) investigated individual differences in face recognition as predicted by holistic processing using a regression rather than subtraction method as suggested by Wilmer et al. (2012). They evaluated adult performance on the CFMT (Duchaine & Nakayama, 2006), composite task, and part-whole task to determine if face recognition scores could be predicted by holistic processing. Using the regression method, they found a robust relationship between face recognition and measures of holistic processing, providing further evidence that holistic processing is an important aspect of successful face recognition skill.

Together, 3 of the 4 studies described above found a consistent correlation between face recognition scores and configural processing of faces. These studies provide strong evidence that individual differences in configural processing may explain the wide range of face recognition skill seen in adulthood. This finding has serious implications for the understanding of face recognition in both typically developing and DP participants, as well as training of face recognition abilities. If individual differences in configural processing are predictive of face recognition abilities, this information could be used to inform training studies of face recognition and might also be used to identify individuals at risk for DP. In addition, these possibilities present an opportunity to identify children with DP early in life and train them to attend to global features of the face. However, it may not be the case that children's configural processing skills are predictive of face recognition abilities in the same way that they are for adults. Thus, one of the aims of the current thesis is to examine how face recognition skills vary with configural processing abilities in childhood populations.

## **Feature-Based Processing**

The research described in the previous section highlighted the importance of the face “whole” rather than “parts” for recognizing faces. However, it is likely that both configural *and* part-based structure provide essential information needed for face recognition. Although the configural structure of the face may be very important for face recognition, replacing face parts undoubtedly would interfere with our ability to recognize a face and would affect our perception of the face “whole.” Therefore, the importance of the individual face parts should not be ignored, bringing attention to whether or not *particular* regions provide more useful information for face recognition than others (see Shepherd, Davies, & Ellis, 1981 for a review of the pre-1981 literature on this topic).

The relative importance of some areas of the face over others has been investigated in several ways. One approach has been to investigate the areas of the face that seem to be most salient for participants during face recognition experiments. Early studies on this topic simply measured the percentage of time that participants spend on each area of the face during a face recognition task. Using this method, several groups (e.g. Althoff & Cohen, 1999; Barton, Radcliffe, Cherkasova, Edelman, & Intrilligator, 2006) have shown that adults spend the majority of their viewing time on the eye region, with almost all of their viewing time divided between the eyes, nose, and mouth (see Henderson, Williams, & Falk, 2005; Shepherd et al., 1981 for a brief review of this literature). More specifically, Henderson et al. (2005) found that participants devoted on

average 4 of 10 seconds on the eye region of the face when learning face stimuli, whereas all other regions were attended to for less than a second each.

Other studies have manipulated the presentation of a face to examine which features seem most essential for recognition. Most investigations of this question have found that the eye region is most salient for face recognition, followed by the mouth and nose, in no particular order (the relative importance of the nose and mouth vary across studies and methodologies). For example, Haig (1985) presented adult participants with faces covered by masks with apertures that revealed particular parts of the face in isolation. Results showed that, of the internal features, participants were best able to identify faces that showed the eye/eyebrow region, followed by the mouth/upper lip area. In a subsequent study, Haig (1986) exchanged cardinal features of faces and participants had to indicate which of several faces was most similar to a target face. Again, the results supported the hypothesis that, of the central features, the eye/eyebrow region was most used for judging face similarity, followed by the mouth, and then the nose. These results replicated those found by Davies, Ellis, and Shepherd (1977) who used a similar method of feature substitution with participants choosing which of four faces most closely resembled a target face. Furthermore, Fraser, Craig, and Parker (1990) completed a similar study by examining response speed when features of the face were either omitted or substituted. Like previous work, they found that the eye region of the face was a more salient cue than the nose or the mouth regions<sup>3</sup>.

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<sup>3</sup> This study, like many other early studies, included hair in their stimulus faces. Therefore, the hairline of the face was included as an area-of-interest. They found that the face outline was the most salient feature. However, because hair changes so frequently, the present thesis focuses on the features of the face itself, like many recent studies, rather than the hair or hairline, as a cue for identification.

More recent studies using advanced methodologies such as the Bubbles technique (Schyns, Bonnar, & Gosselin, 2002), response classification techniques (Sekuler et al., 2004), and eye tracking methods (Barton et al., 2006; Henderson et al., 2005; van Belle, Ramon, Lefevre, & Rossion, 2010), have supported the hypothesis that the eye region, in particular, is the most salient feature in face recognition.

However, not all evidence points to the eyes as being the most important feature for face recognition. Sadr, Jarudi, and Sinha (2003) presented participants with photographs of familiar celebrity faces, some of which had missing eyebrows and others of which had missing eyes. They found that photographs that omitted the eyebrows were more difficult to recognize than photographs omitting the eyes suggesting that the eyebrow region of the face may provide more information for identification than was originally believed. Furthermore, Hsiao and Cottrell (2008) reported that, when participants were limited to two fixations on a face memory task, they preferentially fixated the nose region, rather than the eyes. Although they found that allowing two fixations yielded better performance than one, additional fixations did not improve performance, suggesting that two fixations to the nose was sufficient for face recognition. Others have reported that it is the “core” features together—the eyes, nose, and mouth—rather than any particular features in isolation, that facilitates face recognition (Gosselin & Schyns, 2001).

In general, the majority of the literature investigating *typically developing adults* tends to support the hypothesis that the eye region is particularly important for face recognition. Yet, another approach for evaluating the relative importance of different



face parts for successful face recognition has been to examine special populations who experience face recognition difficulties. In these groups, qualitative differences in eye tracking patterns as compared to typically developing populations may provide key insights as to what aspects of the face require attention for successful recognition. These evaluations have typically focused on two groups; those with Autism Spectrum Disorders (ASD) and those with DP.

Several groups have suggested that adults with ASD have impaired facial recognition abilities compared to non-ASD populations (Hedley, Young, & Brewer, 2012; see Weigelt, Koldewyn, & Kanwisher, 2012 for a recent thorough review of face identity recognition in ASD). Recently, Weigelt et al. (2012) published a thorough review of the studies published since April 2011 examining face recognition abilities of adults and children with ASD. They concluded that, generally, those with autism spectrum disorders demonstrate a quantitative, but not qualitative, deficit in face identity recognition compared to their typically developing peers. In other words, although those with Autism showed classic hallmarks of face recognition such as the inversion effect, composite effect, and part-whole effect, they showed severe face recognition impairment on simple tasks of face memory. Furthermore, they found that limitations in face recognition in the ASD population were specific to faces and restricted to face *memory*, with at least a 30 second delay, rather than deficits in face perception or discrimination. However, they did find one rather robust qualitative difference in face processing between those with ASD and their typically developing peers – use of information in the eye region (Weigelt et al., 2012). For example, Rutherford, Clements, and Sekuler

(2007) varied the eye-to-eye distance and the mouth-to-nose distance in a face discrimination task and found that those with ASD were impaired in their sensitivity to eye spacing<sup>4</sup>. Similarly, Joseph, Ehrman, McNally, and Keehn (2008) varied featural changes alone and found impairments in their ASD sample only for trials where the eyes varied. Finally, both Wolf et al. (2008) and Riby, Doherty-Sneddon, and Bruce (2009) varied both featural and configural information of faces and found impairments in sensitivity for those with ASD, but only for the eye region. Thus, of the completed studies that included face discrimination comparing eyes versus mouth changes (e.g. eye or mouth substitution or distance between the eyes), those with ASD consistently showed impairment in sensitivity to eye changes, but not mouth changes.

Similarly, adults and children with prosopagnosia have demonstrated less attention to the eye region of the face compared to controls. For example, deficient processing of the eyes as measured by face recognition tasks has been demonstrated in cases of acquired prosopagnosia using methods such as the bubbles technique (Caldara et al., 2005), face recognition tasks with feature substitution (Ramon & Rossion, 2010), and eye tracking methods (Stephan & Caine, 2009; Xivry, Ramon, Lefevre, & Rossion, 2008)<sup>5</sup>. However, importantly, not all cases of acquired prosopagnosia show evidence of

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<sup>4</sup> Note that changes in sensitivity to spacing is often regarded as a “configural” rather than “featural” change. However, as is outlined below, featural and configural changes, in cases such as these, are often difficult to separate. In this case, those with ASD show a configural or relational processing deficit, but only for one feature, the eyes. Furthermore, those with ASD do not show reliable impairments in the inversion effect, composite effect, or part-whole task. Therefore, this impairment was considered feature-specific rather than configural (referring to the entire face) in nature.

<sup>5</sup> Stephan and Caine (2009) measured attention to the internal features versus external features, rather than individual features (e.g. eyes, nose, and mouth) separately.

abnormal featural processing (e.g. Le, Raufaste, & Demonet, 2003; Rizzo, Hurtig, & Damasio, 1987). Nonetheless, abnormal eye-tracking patterns on face recognition tasks have been demonstrated in cases of DP as well. First, an examination of four adults with DP showed a greater degree of attention to external features (e.g. forehead and chin) as compared to controls. However, the authors did not report a direct comparison of attention to the eyes between the two groups (Schwarzer et al., 2007). Finally, a case study of a child with DP (Schmalzl, Palermo, Green, Brunson, & Coltheart, 2008) suggests that children with DP may also spend an abnormally limited amount of attention on the eye region of the face relative to typically developing controls. Regardless, future work should examine tracking patterns of typically developing children, children with ASD, and children with DP to examine how attentional factors may be playing a role in face recognition deficits.

As outlined above, investigations of the relative importance of different face features has largely relied on group data or case studies rather than investigations of individual differences. This is particularly interesting given the rather broad assumption that attention to the “core” areas of the face, especially the eyes, are particularly important for face recognition. To date, only one study, published as a non-peer-reviewed study, has investigated individual differences in attention to different face parts as they related to face recognition ability. Yang, Wang, Ge, Sun, and Xiao (2012) hypothesized that, if attention to particular regions of the face is important for face

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Therefore, it is possible that the differences in attention seen in their case of AP is not specific to the eye region. Nonetheless, this patient exhibited abnormal featural processing compared to controls.

recognition, then attention to those areas should significantly correlate with face recognition ability. They examined 5 areas of interest (whole face, eyes, nose, mouth, and other face areas). Participants completed an old-new face recognition task while their eye movements were recorded with an eye tracker. Results showed that, in both the learning and recognition phases of the test, face recognition scores negatively correlated with attention to the eyes. This finding held for both fixation duration and fixation count. They did not report raw looking times. In other words, those devoted a greater proportion of looking to the eye region (measured in number of fixations and duration of looking time) demonstrated poorer face recognition scores. No other AOIs were significant. One caveat of this finding is that the participants included in this study were undergraduates of a University in China. Recent studies on the other-race-effect and eye tracking across different races have suggested that different tracking patterns may be differentially beneficial for different races (Blais, Jack, Scheepers, Fiset, & Caldara, 2008). Therefore, the findings of this study may not generalize to non-Chinese populations. A second caveat is that this study included only 5 areas of interest, limiting the ability to analyze the importance of individual face features that may be important, such as the eyebrows (see Sadr et al., 2003). Finally, it was not specified in the description of the method for this study if the faces used during the learning phase were identical to the faces used during the recognition phase. Ideally, photographs used for testing will employ changes in lighting and/or orientation to avoid feature-matching. Nonetheless, the findings of this study are perplexing given the large amount of previous literature suggesting that the eyes are important for face recognition. One might have expected that attention to the

eyes should *positively* correlate with face recognition rather than *negatively* correlate.

Future work should clarify this finding.

Regardless, there has yet to be a *peer-reviewed empirical* investigation, especially with childhood populations, that directly examines the relationship between attention to various regions of the face (e.g. eyes, nose, and mouth) and an established, validated measure of face recognition such as the CFMT. Without such a study examining these relationships in typically developing populations, it is difficult to substantiate claims that *any* region (e.g. eyes) of the face is particularly important for face recognition. In fact, face recognition patterns for children might not be precisely adult-like. For example, Taylor, Edmonds, McCarthy, and Allison (2001) found that the ERP N170 response, typically seen in response to face stimuli, is stronger when children are presented with eye stimuli rather than full-face stimuli, suggesting that young children may process the eyes more efficiently than the full face, contrary to adults who show a stronger N170 response when the full face is presented. Yet, knowing whether or not this is the case is essential for understanding face recognition disorders and subsequently developing training programs for these populations. Thus, one of the goals of the present proposal will be to investigate individual differences in attention to various regions of the face in relation to performance on established tests of face recognition for childhood populations.

### **Configural and Feature-Based Processing: Mutually Exclusive?**

These two theories, configural processing versus part processing, need not be mutually exclusive. For example, although the literature tends to support the notion that the eye region is particularly important for face recognition, it is important to note that

the eyes, in and of themselves, are likely not sufficient for successful face recognition (Shepherd et al., 1981; Yovel & Duchaine, 2006). Therefore, other areas of the face, especially the nose and mouth, likely make a large contribution to face recognition in the everyday environment. For this reason, it is difficult to separate the processing of local features from the overall configuration of the face.

Furthermore, it may be that particular areas provide more global information than others. For example, it may be that areas of the face not typically attended to (e.g. the forehead or cheeks) do not provide as much structural information that indicate individuality as other parts of the face (e.g. the eyes, nose, and mouth). Therefore, attention to particular face parts, such as the eyes, may be necessary for skilled configural processing of faces (Ramon & Rossion, 2010).

This idea is supported by several lines of evidence. First, Leder, Bruce, and colleagues have demonstrated that the inversion effect, typically thought to be a measure of configural processing, is at least in part dependent on local features, specifically the eye region (Leder & Bruce, 2000; Leder, Candrian, Huber, & Bruce, 2001). In fact, they demonstrated that the inversion effect can be produced for the eyes in isolation of the rest of the face (Leder et al., 2001). Second, Bukach et al. (2006) investigated a case of severe acquired prosopagnosia and found that configural processing was impaired, but only for the upper part of the face suggesting that configural processing may be somewhat feature-based. Similarly, DeGutis, Cohan, Mercado, Wilmer, and Nakayama (2012) recently examined configural processing with a large group of adults with developmental prosopagnosia. Using the part-whole task (Tanaka & Farah, 1993), they

found evidence of normal holistic processing of the mouth and nose but a part, rather than whole, advantage for the eye region, unlike controls. This suggests that holistic processing may be impaired for the eye region in cases of prosopagnosia, and thus, holistic processing of the eye region may be particularly important for face recognition. Furthermore, these findings are supported by studies examining locations of *first* fixations that may optimize the ability of picking up as much configural information as possible in just one or two fixations. For example, van Belle et al. (2010) examined fixations sequentially and found that early fixations tended to fixate near the eye region of the face. Interestingly, in a similar analysis, Hsiao and Cottrell (2008) found that, when limited to just two fixations, participants tended to fixate the nose region of the face. Although this finding seems contrary to the above-mentioned literature, the difference in fixation location may be a result of limiting viewing time to just two fixations. However, see Henderson et al. (2005) for an example of how limiting free viewing of faces can hinder face recognition performance. This calls into question the relative importance of the eye region, but also raises the possibility of the importance of a centrally located fixation for efficient configural processing of the entire face.

Second, there is evidence that different parts of the face may be more informative for recognition in different races that have slightly different facial structures. In other words, although the eye region may be most informative, from a structural standpoint, for Caucasian faces, this does not mean that the eye region will provide the most structural information for other race faces. This may seem counter-intuitive given the vast amount of literature that supports the notion that the eyes are important for face recognition and

configural processing. Nonetheless, Blais et al. (2008) appropriately point out that the majority of this research has examined Western Caucasian individuals, with little regard to possible differences in other races. However, recent research has begun to address this issue, with interesting findings. For example, Blais et al. (2008) examined eye-tracking patterns in both Caucasian and Asian adults. Participants were presented with face recognition tasks using both races of faces. Regardless, of the race of the stimuli, Western Caucasian participants tended to fixate the eye region of the face, followed by the mouth region. In contrast, Asian participants mainly fixated the more central nose-region of the face. As would be expected, both groups were better at recognizing faces in their own race (Blais et al., 2008).

Similarly, Hills and Lewis (2006) hypothesized that it may be possible to minimize the own-race-bias for face recognition by training individuals to attend to the features that provide the most discriminative value for a particular race. They capitalized on the finding that African faces, more so than Caucasian faces, differ in the lower regions of the face. They trained Western Caucasian individuals to attend to the lower regions of the face during a face training task and subsequently found that the training improved the ability of the Caucasian participant to recognize African faces. This finding supports the notion that the *features* of the face that provide the most structural or *configural* information may differ across races.

Substantiating these findings, Tan, Stephen, Whitehead, and Sheppard (2012) found that Malaysian Chinese individuals, who are often exposed to both Chinese and Caucasian faces, showed eye tracking patterns that were commonly seen in both East



Asian (attention to the nose) and Western observers (attention to the eyes) but did not show evidence of increased attention to the lower region of the face when looking at African faces.

These studies not only shed light on how different areas of the face may better inform a person's identity than others, depending on their race, but also highlight reasons why we see evidence of the other-race-effect (Malpass & Kravitz, 1969) – the highly documented finding that it is easier to recognize faces of races that one has regular exposure to, typically their own, than other races (see Meissner & Brigham, 2001 for a meta-analysis of this literature). Furthermore, configural processing is most prevalent for own-race faces than other-race faces (Michel, Rossion, Han, Chung, & Caldara, 2006). This finding further elucidates the idea that we may learn particular *features* that provide the most information about *configural* structure in the race of which we have the most exposure, our own-race. Therefore, it is likely that we develop the ability to best discern differences between faces that are most prevalent during development and therefore provide the highest diagnostic value for face recognition (Tan et al., 2012).

### **Lessons Learned from Computer Vision**

Another avenue of research that is relevant to this proposal is the use of computer systems for face recognition. Since the 1970s, engineers have been attempting to create computer systems that are capable of face recognition from both still images and videos. These advances are extremely important for entertainment purposes (e.g. video games), smart cards, information security, and law enforcement and surveillance (Zhao, Chellappa, Phillips, & Rosenfeld, 2003). Although the currently developed systems are

still far from being able to recognize faces at the level of the human perceptual system (Zhao et al., 2003), the success of systems modeled after the human recognition system may provide insight as to what geometrical aspects of the face are most beneficial for face recognition.

In general, the success of computer face recognition systems are dependent on their ability to detect a face, extract the relevant features, and identify the face. Interestingly, within this realm, the step of face identification has, generally, been divided into three types of models: those using holistic approaches (e.g. eigenfaces and Fisher faces), those using feature-based approaches, and those taking a hybrid approach (Zhao et al., 2003). Holistic approaches use the whole face as input to the system, a method based on principle component analysis. These are template-matching systems in which each template is a prototype face or an abstract reduced-dimensional feature vector obtained by processing the face as a whole (Etemad & Chellappa, 1997). Feature-based systems, on the other hand, use local features (e.g the eyes) to extract location information and local statistics such as the sizes of and distances between major features (Etemad & Chellappa, 1997). As the human perceptual system likely uses both holistic and feature-based information for face recognition, the hybrid approach takes both models into account (Etemad & Chellappa, 1997; Zhao et al., 2003).

The benefit of these systems for understanding human face perception is that computer models such as these may shed light on the dimensions of difference between faces that may provide the most information for face recognition. However, the findings regarding the areas of the face that may be most useful for face recognition computer

systems have been mixed, and often depend on the particular kind of model used. For example, Etemad and Chellappa (1997) developed a feature-based face recognition model by the calculated discrimination power of different parts of the face. When analyzing the different parts of the face by comparing horizontal bands, they found that the different areas of the face are largely comparable in their discriminative power, however, the area between the nose and the mouth yielded the most discriminative power relative to other horizontal bands. Furthermore, in their model, the discriminative power of the whole image was much larger than the discriminative power of any part in and of itself.

On the other hand, Ballihi, Amor, Daoudi, Srivastava, and Aboutajdine (2012) used a curve-based analysis that represents facial shape as a collection of curves. They found that the curves in the top half of the face (stemming from the nose) were best predictive of face identity than curves stemming from the nose but representing the lower half of the face. However, the authors pointed out that the regions in the upper half of the face highlighted by their analysis is a region that is, perhaps, more robust to facial expression than the mouth area of the face. This highlights the importance of recognizing the differences between computer recognition systems and human face perception—for human face perception, the use of human facial expression may, in fact, be an important part of face recognition rather than something to be discarded, as is the case with computer recognition systems.

## The Present Studies

The goal of this thesis was to examine the aspects of the face that are most important for successful face recognition and whether we can use this information to predict, identify, and possibly explain face recognition difficulties in children.

Furthermore, if the information used in face recognition can be better understood, this could then inform studies aimed at training face recognition abilities in children.

Children are the main focus of this proposal because 1) it is not yet known if configural or feature-based processing is predictive of face recognition skills in the same way as adults and 2) this is the population for which being able to predict a face recognition impairment is most imperative – as children are still developing social skills and are possibly young enough to benefit from an intervention.

Based on the literature cited above, these studies were fueled by the central hypothesis that *children who show evidence of a greater degree of configural processing and greater attention to the eye region will perform better at tasks of face recognition than children who process faces in a less global manner and devote less attention to the eye region.*

More specifically, the experiments included in this thesis examined the following hypotheses:

<b>AOI predicts Face Recognition Score</b>	Children with higher face recognition scores will spend more time and have more fixations on the eye region during face recognition tasks. Other AOIs will also be evaluated.
<b>Configural Processing predicts Face Recognition Score</b>	Children who show a greater degree of configural processing of faces will have higher face recognition scores on face recognition tasks.
<b>AOI predicts Configural Processing</b>	Children who show a greater degree of configural processing of faces will show more fixations to the eye region on eye tracking tasks.
*AOI = Area-of-Interest, FR = Face Recognition	

Table 1. Hypotheses Tested in the Present Thesis

These hypotheses were addressed across four studies. Experiment 1 aimed to examine what features of the face children attend to during a standard face recognition task. The goal was to determine which features of the face may be most informative for face recognition and to determine data-based areas-of-interest to be examined in Experiment 2. Experiment 2 examined typically developing 8-year-old children on a series of tasks including: two face recognition tasks based on the CFMT (Duchaine & Nakayama, 2006), one with children’s faces and the other with adult faces; two part-whole tasks (Tanaka & Farah, 1993), one with children’s faces and the other with adult faces, included to obtain a measure of configural processing; and an object recognition task, created by our lab and modeled after the CFMT. Furthermore, eye-tracking data was collected during both face recognition tasks. Using these tasks, we were able to assess individual differences in children’s face recognition abilities based on the hypotheses listed above. Finally, Experiments 3 and 4 used similar methodology as Experiment 2, but with a different sample of participants. Experiment 3 sampled from children who had participated in previous experiments using the face recognition tasks

mentioned above. From this sample, two groups were created based on their initial face recognition scores and were asked to return to the lab for testing. These two groups (high performers and low performers, matched in age at time of testing) were then compared for differences in configural processing and attention to various parts of the face. Thus, the overall purpose of Experiment 3 was to substantiate the findings of Experiment 2. Finally, Experiment 4 collected data from a sample of children with developmental prosopagnosia with the hypothesis that, like the adult-literature, these children may show evidence of abnormal configural processing and eye-tracking patterns compared to their typically developing peers.

## **CHAPTER 2: Experiment 1**

### **Introduction**

The overall goal of Experiment 1 was to examine which parts of the face are most salient for children during a face recognition task. Feature-saliency was examined in two ways. First, we examined attention to various regions of the face to determine which parts children attended to the most. More specifically, we hypothesized that children, like adults, would devote the majority of their fixations to the eye region of the face, followed by the mouth and nose in no particular order. Second, we analyzed attention to various areas-of-interest (AOIs) to see if face recognition performance, as measured by accuracy, varied systematically with attention to specific areas of the face. Specifically, we hypothesized that, if the eye region of the face is particularly important for successful face recognition, children with higher accuracy scores should devote more attention to the eye region of the face than children with lower accuracy scores. The selected areas of

interest for this study were chosen based on previous adult literature—given the attention to the eyes, nose, and mouth, these areas were included as the internal, or core, AOIs. Furthermore, due to the hypothesized saliency of the eyebrows proposed by Sadr et al. (2003), we included the eyebrows as a separate AOI. Finally, we wanted to examine the importance of the less-attended-to areas of the face and perhaps probe the hypothesis that attention to these less informative areas may interfere with successful face recognition, as suggested by Schwarzer et al. (2007). Therefore, we included the forehead, cheeks, and chin as additional AOIs.

## **Method**

### **Participants**

Thirty-three (13 males) typically developing 7- and 8-year-old children were included in the final sample ( $M=7;9$ , range = 7;4—8;2). Children were recruited through the University of MN, Institute of Child Development participant pool. Three additional children were excluded from the sample due to equipment failure (2) and withdrawal from the study (1).

### **Apparatus**

Eye tracking data were collected using a Tobii Eye Tracker 1750 paired with Tobii Studio version 1.0. Stimuli were presented on a screen with a 17-inch monitor set at a resolution of 1024x768 pixels. For this type of eye-tracker, the cameras used to track eye movement are built into the screen. Thus, nothing was attached to child and no head-mount was used. Standard 9-point calibration was used. For optimal calibration, participants were seated approximately 60 cm from the screen. The eye-tracker sampled

the position of the participants' eyes at a rate of 60Hz. Fixation count and fixation duration data were exported after the end of the experiment for each AOI. For each child, the number of trials in which there was scorable tracking was calculated. Although no children were excluded for limited tracking data due to a small sample size, tracking was largely successful for this age group ( $M = 17.21$  trials out of 20 possible 20 trials, Range = 7 – 20 trials). Data were collected using a Dell computer on which all tests were run.

## **Tasks**

### *Eye Tracker Task: Face Recognition*

This task was created by our lab to assess attention to various parts of the face during face recognition. The face images used in this task were provided by the Computer Vision Laboratory, University of Ljubljana, Slovenia (Peer; Solina, Peer, Batagetj, Juvan, & Kovac, 2003). Children were seated in front of a computer and were read the instructions by a trained experimenter. On each trial, a learning face was inlaid in an oval that was 26 cm high x 17 cm wide, centered on the screen, and presented to the child for 5 seconds. Subsequently, three faces, each inlaid in an oval 13 cm high by 8.5 cm wide in size, one matching the target face and two foils, were presented on the screen for unlimited duration and the child was asked to choose which of the 3 faces matched the previously seen target face. These test faces were separated from each other by 2.5 cm with the center face centered both vertically and horizontally. The child noted his/her choice by clicking the face using the computer mouse. This continued for 20 trials. As we were particularly interested in how children acquire information that is later used for recognition and how this varies with their face recognition performance, we collected



eye-tracking data during the learning phase of each trial using a Tobii eye tracker. As previously indicated, each face was divided into the following areas-of-interest (AOIs): eyes, eyebrows, forehead, cheeks, eyebrows, nose, mouth, and chin. Trials were included so long as tracking data were collected during the learning phase.

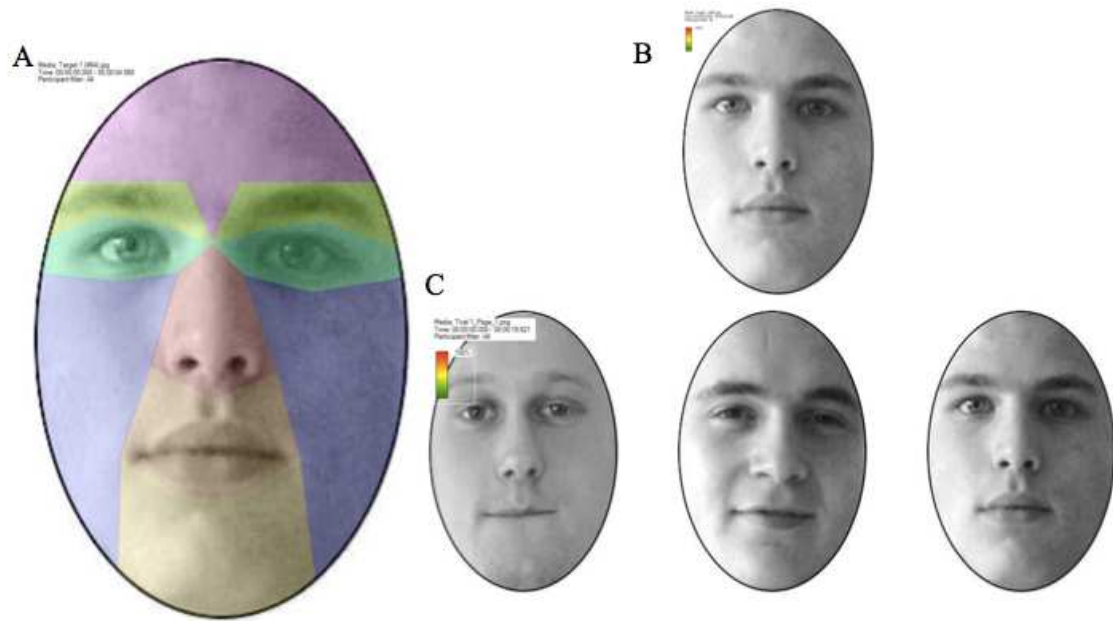


Figure 3. The Eye Tracker Task: Face Recognition. In this task, AOIs were defined as seen in (A). On each trial, participants were presented with a face for 5 seconds (B) and subsequently asked to choose the target face from a line-up of the same face and two foils (C).

#### *Cambridge Face Memory Task for Children (CFMT-C)*

Cambridge Face Memory Task for Children (CFMT-C; Figure 4; Duchaine, Nakayama, Pellicano, & Pimperton, 2006) is a childhood version of the Cambridge Face Memory Task (CFMT; Duchaine & Nakayama, 2006). The purpose of this task was to examine the face recognition skills of children. This task differed from the Eye Tracker Task in that children were asked to remember the same 5 faces throughout the task, placing more demands on working memory. Also, the images of the faces used for

testing were not identical images as those seen during learning; rather, they differed in orientation, eliminating the possibility that children were simply memorizing local features of the photographs rather than facial identity.

Children were seated in front of a computer and were read instructions from the screen by a trained experimenter. Before the start of the test, the participant was presented with three practice trials displaying a cartoon character to ensure that they understood the rules of the game. The test was divided into three phases. In the first phase, children were asked to learn the faces of 5 adult males. For each face, children were presented with three sequential views (front, 45 degrees, and -45 degrees, for 5,000 ms each; see Figure 4, part i) of the face and then subsequently asked to pick the target face from a lineup of two faces across three trials (2 alternative forced-choice; see Figure 4, part ii). For all trials, the faces remained on the screen until a choice was made. This process was repeated for each of the 5 faces. In phase 2, children were allowed to review the 5 target faces for 20 seconds and were then presented with 25 binary forced-choice trials of a target face (which could be any one of the five faces learned in phase 1) and a distractor. In addition, the photographs in phase two had a different orientation than those of phase 1 (see Figure 4, part iii). Finally, phase 3 was identical to phase 2 with the exception that the faces were masked with noise (20 trials). Children received a score reflecting their percent correct across all trials. Previous data collected in our lab has shown that this test has high test-retest reliability,  $r=0.69$  and is effective in identifying children with DP.

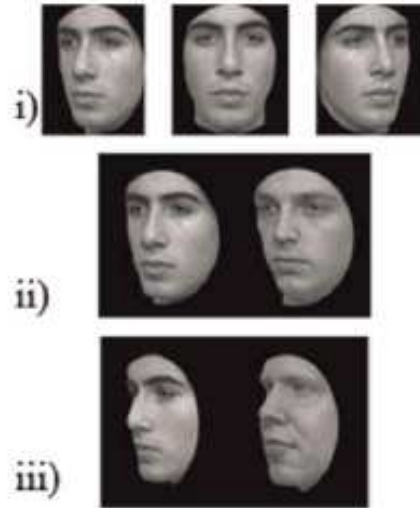


Figure 4. The Cambridge Face Memory Task for Children. In phase 1, children were asked to learn a face (i) and then were tested with 3 2-alternative-forced-choice trials for each of 5 faces (ii). In phase 2, children were first allowed to review all 5 faces simultaneously for 20 seconds and then were presented with 2-alternative forced-choice trials that contained a target face and a distractor (iii). The target face differed from phase 1 in orientation. Finally, phase 3 was identical to phase 2 with the exception that all faces were masked with noise. Reprinted with permissions from Taylor & Francis from Wilson et al. (2010).

### *Object Recognition Task*

To assess the child's ability to recognize objects, we created an object recognition task identical in format to the CFMT-C using eyeglasses as stimuli rather than faces. In addition to assessing object recognition, this task served the purpose of ensuring that the child could understand the instructions of the CFMT-C, as the rules were the same. Children were presented with three practice trials displaying backpacks that differed greatly to ensure that the child understood the rules of the game. Like the CFMT-C, the test was divided into three phases. In the first phase, children were asked to learn and

memorize 5 pairs of glasses. For each pair, children were presented with three sequential views (front, 45 degrees, and -45 degrees, for 5,000 ms each; see Figure 5, part i) of the glasses and then subsequently asked to pick the target from a lineup of two pairs of glasses (one foil and one distractor) across three trials (2 alternative forced-choice; see Figure 5, part ii). This process was repeated for each of the 5 pairs. Like the CFMT-C, phases 2 and 3 presented the pairs of glasses in a new orientation and masked with noised respectively. Children received a score reflecting their percent correct across all trials.

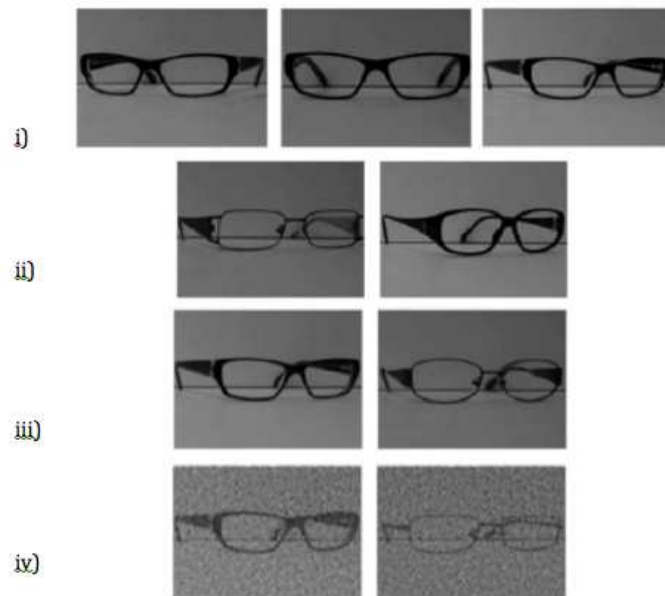


Figure 5. The Object Task. In phase 1, children were asked to learn a pair of glasses (i) and then were tested with 3 2-alternative-forced-choice trials for each pair of glasses (ii). In phase 2, children were first allowed to review all 5 faces simultaneously for 20 seconds and then were presented with 2-alternative forced-choice trials that contained a target and a distractor (iii). The target differed from phase 1 in orientation. Finally, phase 3 (iv) was identical to phase 2 with the exception that all faces were masked with noise. Image adapted and reprinted with permissions from Taylor & Francis, from Dalrymple,

Corrow, Yonas, and Duchaine (2012).

## Procedure

After completing the consent process, children were seated in front of the eye tracker and the system was calibrated to accurately track the child's gaze. Then, children completed the eye tracker task and their gaze was recorded. Following the completion of that task, children completed the CFMT-C, the Object Task, and an emotion recognition task<sup>6</sup> in random order. The Eye Tracker Task was always completed first to maximize the likelihood that the children would be able to remain still for eye tracking.

## **Results**

### **Evaluation of Individual Measures**

#### *Eye Tracker Task: Face Recognition*

The purpose of the Eye Tracker Task was to collect eye-tracking data during face learning. Thus, we were less interested in their score on this task than the amount of time they spent looking at each AOI. However, evaluating scores on this test is important for ensuring that children were actually learning the faces presented in the learning trials. For each child, a score was calculated to reflect the percentage of trials (out of 20) in which the child gave a correct response. With chance performance equaling 33% (0.33) correct, results showed that children were highly successful at identifying the faces presented in this task [ $M = 0.81$ ,  $SD = 0.118$ ]. Thus, if anything, children showed a slight

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<sup>6</sup> Children completed an emotion recognition task purely for the purposes of piloting this task. Approximately half of the children completed the Reading the Mind in the Eyes Task (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) and the other children completed a new emotion recognition task created by our lab that roughly modeled the format of the CFMT-C. However, we were not interested in how scores on this task varied with face recognition performance. These tests were included simply for piloting purposes.

ceiling effect. Therefore, the tracking data collected during learning trials should reflect successful face recognition.

### *CFMT-C*

The CFMT is a highly reliable face recognition task often used for adult face recognition studies. The childhood version, the CFMT-C, is an adapted version of the CFMT intended for children. Previous studies in our lab have shown that the test-retest reliability of this task is high [ $r=0.69$ ] and this test is successful for identifying face recognition deficits in cases of developmental prosopagnosia. In the present sample, a score was calculated for each participant reflecting the percent correct out of 60 trials [ $M = .795$ ,  $SD = 0.09$ ].

### *Object Recognition Task*

The purpose of the Object Recognition Task was to ensure that participants did not suffer from a general agnosia impairing their ability to recognize objects, not specific to faces. In addition, as the format of this test was identical to the CFMT-C, this task also served to ensure that the child understood the task instructions. In other words, if children performed within normal range on the Object Task, poor performance on the CFMT-C could not be explained by lack of understanding of the instructions. Like the CFMT-C, in the present sample, a score was calculated for each participant reflecting the percent correct out of 60 trials [ $M = 0.779$ ,  $SD = 0.078$ ]. Because this was a binary forced-choice task, chance performance was 50% correct. Based on these data, we concluded that the Object Task did not have a floor or ceiling effect. However, it should be noted that CFMT-C performance significantly correlated with object recognition

performance [ $r = 0.369$ ,  $p < 0.05$ ]. To account for this, each of the following analyses were performed in two ways. First, as planned, we examined correlations between attention to various AOIs and CFMT-C score. Second, as suggested by Wang et al. (2012) and Wilmer et al. (2012), we regressed performance on the Object Task out of performance on the CFMT-C in order to isolate the remaining variance that explained face recognition performance as opposed to more general object recognition abilities and the ability to understand the task instructions. Then, each AOI could be correlated with this remaining residual to examine how attention to these areas systematically varied with a direct measure of face recognition skill.

### **Analysis of Eye Tracking Data**

To evaluate the relative importance of different areas of the face in face recognition, two analyses were completed. First, average looking times to each area of the face were evaluated across all participants. This analysis allowed us to examine if children, like adults, devote the majority of their attention to the eyes, nose, and mouth regions when learning a face. Second, we were interested in how individual differences in attention to the face were predictive of face recognition skill.

We first examined the amount of time that children devoted to each region of the face, collapsed across all participants. Results for both number of fixations and duration of looking, presented as a proportion of total looking (looking time/fixation count divided by total looking time/fixation count), to each area are presented in Figure 6. Consistent with the previous literature, children devoted the majority of their attention to the eyes (0.42 duration/0.34 fixation) followed by the nose (0.26/0.28), mouth (0.13/0.12), and

eyebrows (0.12/0.12). Interestingly, children devoted very little attention to non-core areas of the face such as the cheeks (0.06/0.05), forehead (0.04/0.04), and chin (0.01/0.01).

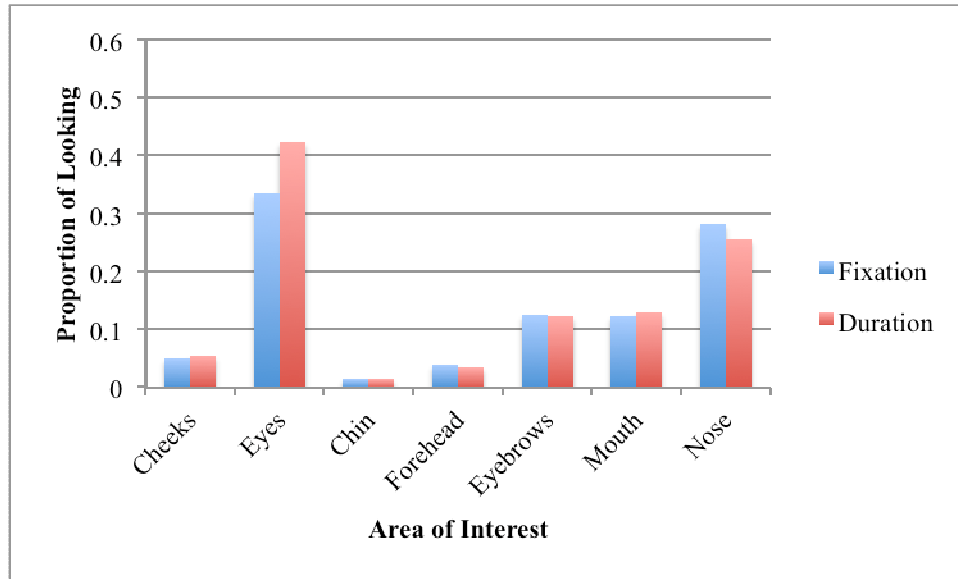


Figure 6. Proportion of Attention to each AOI in Experiment 1. Blue and red bars reflect proportion of fixations and duration of looking time to each AOI, respectively, during learning trials of the Eye Tracker Task.

Second, we were also interested in whether or not attention to particular areas of the face was predictive of face recognition scores as measured by the CFMT-C. Such an analysis required a bonferroni correction for 7 different comparisons; one for each area of interest, resulting in a critical p-value of  $p = 0.007$ . Correlations between each AOI and performance on the CFMT-C are listed in Table 2.



	Cheeks	Eyes	Chin	Forehead	Eyebrows	Mouth	Nose
Fixation	-.065 (.718)	.553 (.001)	-.318 (.071)	-.337 (.055)	-.313 (.076)	.263 (.140)	-.121 (.502)
Duration	-.030 (.868)	.394 (.023)	-.316 (.079)	-.310 (.079)	-.333 (.058)	.322 (.068)	-.193 (.282)

Table 2. Correlations between the CFMT-C Scores and Attention to each AOI on the Eye-Tracker Task. Values listed are Pearson correlations with 2-tailed significance values in parentheses. The corrected bonferroni p-value is 0.007.

In addition, we analyzed the correlations between each area of interest and the residuals not explained by the Object Task performance after regressing the Object Task from the CFMT-C scores. Again, using a critical p-value of 0.007, the resulting correlations and p-values are presented in Table 3.

	Cheeks	Eyes	Chin	Forehead	Eyebrows	Mouth	Nose
Fixation	.141 (.434)	.474 (.005)	-.144 (.422)	-.367 (.036)	-.438 (.011)	.302 (.087)	-.086 (.633)
Duration	.148 (.412)	.317 (.072)	-.129 (.474)	-.324 (.065)	-.443 (.010)	.325 (.065)	-.160 (.373)

Table 3. Correlations between CFMT-C Residuals and Attention to each AOI on the Eye Tracker Task.

Values reflect the correlation after the variance explained by the Object Task had been removed, and each AOI on the Eye Tracker Task as measured by proportion of fixation count and duration of looking. Values listed are Pearson correlations with 2-tailed significance values in parentheses. The corrected bonferroni  $\alpha$

is 0.007.

Analysis of these correlations revealed a few interesting findings. First, the proportion of fixation count to the eye region was significantly correlated with performance on the CFMT-C regardless of whether correlated with the CFMT-C score or residuals unexplained by the Object Task. All other correlations were not significant. However, it is interesting to note that the eyes and mouth were consistently positively

correlated with face recognitions score, whereas the chin, forehead, eyebrows, and nose were consistently negatively correlated with CFMT-C. Furthermore, correlations between CFMT-C and attention to the chin, forehead, eyebrows, and mouth were marginally significant and may have yielded significant correlations with a larger sample size. These data suggest that attention to the core areas of the face may enhance face recognition whereas attention to more extraneous areas of the face may actually hinder face recognition.

Finally, to further substantiate the difference between children with high face recognition scores on the CFMT-C and children with low face recognition scores, the highest and lowest quartiles (8 children in each group) were compared in their attention to the eye region. These planned comparisons revealed that children with the highest CFMT-C scores attended more to the eye region than children with low CFMT-C scores as measured by both proportion of duration of looking time [ $t(14) = 2.042, p = 0.06$  marginally significant] and proportion of fixations [ $t(14) = 2.807, p < 0.05$ ].

## **Discussion**

The analyses of Experiment 1 yielded the following findings. First, when completing a face recognition task, children devoted the majority of their attention to the eye region of the face followed by the nose, mouth, and eyebrows. Along these lines, they devoted very little attention to the more extraneous areas of the face such as the chin, forehead, and cheeks. To examine how individual differences in face recognition skill may be related to attention to particular areas of the face, we examined the correlations between these measures in two ways. First, we correlated attention to each

AOI with their face recognition score on the CFMT-C. Second, we correlated attention to each AOI with the residuals of the CFMT-C unexplained by the Object Task. This allowed us to isolate face recognition by removing the variance explained by general object recognition skill and task-specific factors such as the ability to understand the instructions. Both analyses yielded a significant correlation with the proportion of fixations to the eye region of the face. Furthermore, when the top quartile and bottom quartiles of children, based on their CFMT-C score, were compared, the eye region again yielded significant differences between the two groups.

These findings support the theory that attention to the eye region of the face is important for successful face recognition in children. In addition, although not significant, the negative correlations between face recognition score and attention to extraneous areas of the face, such as the forehead, suggest that attention to these areas may actually hinder face recognition performance. Although these data support the majority of the literature on this topic, they are not consistent with the only previously published study examining individual differences between attention to various local features of the face and face recognition ability. As summarized above, Yang et al. (2012) had adult participants complete an old-new face recognition task while their eye movements were recorded. They found that face recognition performance negatively correlated with attention to the eye region. Thus, their results conflict with the findings for this study. However, cultural differences may explain this discrepancy. Yang et al. (2012) collected their data from adults at a university in China. Thus, it is possible that

the eye region in Chinese populations provides less discriminative information for identity than in Western populations.

Experiment 1 also provided the opportunity to evaluate the usefulness of each of the measures used. First, we discovered that, although possibly useful for the analysis of attention to the face, the Eye Tracker Task produced a ceiling effect for 8-year-old children, limiting the usefulness of interpreting the scores of this measure. However, the analyses of areas of interest provided preliminary findings useful for formulating hypotheses for planned comparisons in Experiment 2. The CFMT-C and the Object Task, on the other hand, produced scores with no ceiling or floor effect and a distribution of scores large enough to make it possible to pick up individual differences.

Nonetheless, there were a few limitations to this experiment. First, once the participants were divided into 4 quartiles, sample sizes for each group were rather small. Thus, a greater number of participants per group may have yield clearer findings. Second, although the CFMT-C was very effective for examining face recognition skills in children, the Eye Tracker Task had limitations. First, although the faces used in this task were void of hair, they contained many subtle local features that may have provided information about identity (e.g. the location of the eyebrows in relation to the outer contour of the faces or a slight indication of emotion in the mouth region). Because the target face photograph was identical to the photograph used in testing, these cues may have been relied upon for later identification, possibly explaining why there was a ceiling effect. Given that these subtle cues were available, it is possible that children used slightly more local-dependent strategies to complete this task than they did in the CFMT-

C, which does not have these limitations. However, most of these local cues were present in areas other than the eye region. In other words, this test was rather conservative in that, if children were relying on these cues, it likely would have resulted in them spending less time on the eyes overall. Nonetheless, Experiment 2 addressed these concerns by increasing the sample size and abandoning the use of the Eye Tracker Task and instead used two eye-tracker compatible versions of the CFMT.

## **CHAPTER 3: Experiment 2**

### **Introduction**

The main goals of Experiment 2 were to address the limitations of Experiment 1 and, in addition, evaluate the hypothesis that children who demonstrate a greater degree of configural processing strategies are better at face recognition.

Children in Experiment 2 completed tasks aimed at evaluating three questions: 1. Where does the child look at the face during identification tasks (AOI)? 2. How well does the child recognize faces (FR)? 3. Does the child use configural processing strategies for face recognition (Configural Processing)? Based on these questions, Experiment 2 evaluated each of the main hypotheses of this thesis, as listed in Table 1. To attain this goal, children completed two face recognition tasks with eye tracking, two tasks of configural face processing, and one object recognition task.

### **Method**

#### **Participants**

Eighty-five typically developing 8-year-old children (38 males) were included in the final sample ( $M = 8;4$ , age range = 8;0 – 8;11). This age was selected because this

was the age group used in the Experiment 1 and because this is the age of the majority of children whose parents' come to the realization that their child does not recognize faces. In other words, most of the parents who have contacted the lab concerned about their child's face recognition abilities have children of 7-10 years-of-age. In addition, this age group was selected for the purposes of comparison with the children to be tested in Experiment 4, most of whom are in this age range.

Children were recruited through the University of MN, Institute of Child Development participant pool. As is outlined above, evaluation of the hypotheses depended on a face recognition score, eye tracking data, and a measure of configural processing. Therefore, to be included in the analyses, children needed to complete a minimum of the CFMT-C, with reliable tracking data, and the Part-Whole Kids Task. These tasks were chosen as the minimum criteria for inclusion because they have a history of being reliable and these tests have been used and described in previous work. Comparatively, the CFMT-kids and the Part-Whole Adult tasks were developed recently and have never before been run with childhood populations. Thus, the crux of the analyses focuses on the former rather than the latter. Based on these criteria, eight children were excluded from the sample due to equipment failure (5), limited eye tracking (2), and a verbal refusal to cooperate (1).

### **Apparatus**

The apparatus used in Experiment 2 are identical to that of Experiment 1.

### **Tasks**

*Cambridge Face Memory Task for Children (CFMT-C)*

The Cambridge Face Memory Task for Children (CFMT-C; Figure 4; Duchaine et al., 2006) was identical to that of Experiment 1. The only difference was that the images on the screen needed to be slightly enlarged in order to define distinct AOIs for the purposes of eye tracking. Specifically, the images were 312% the size of the images in the original CFMT-C from Experiment 1. Also, rather than the participant pressing a key to choose their response, they gave a verbal response. This was done to prevent children from looking away from the screen to select the correct key to press. Instead, the experimenter pressed the key for them. An example of the AOIs defined for the CFMT-C is presented in Figure 7. Instructions for how AOIs were defined are listed in Appendix 1.

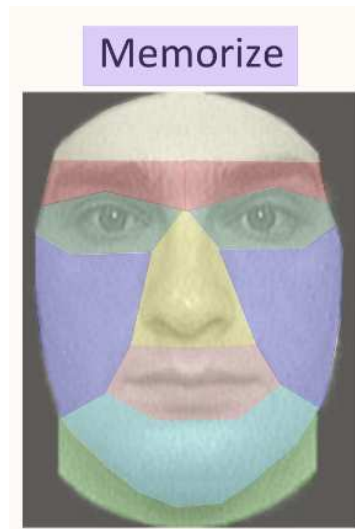


Figure 7. Example of Areas of Interest Defined in the CFMT-C.

#### *Cambridge Face Memory Task for Kids (CFMT-Kids)*

Like the CFMT-C, this task was adapted from the original adult version of the Cambridge Face Memory Task (Duchaine & Nakayama, 2006). In general, the instructions and procedure for this task were identical to the CFMT-C, however, with

three main differences. First, children’s faces were used as stimuli rather than adult faces. Second, participants were required to memorize 6 faces rather than 5 and, thus, overall this version had a greater number of trials (72). Third, the participant was presented with 3-alternative forced-choice trials rather than 2-alternative forced-choice (see Figure 8).

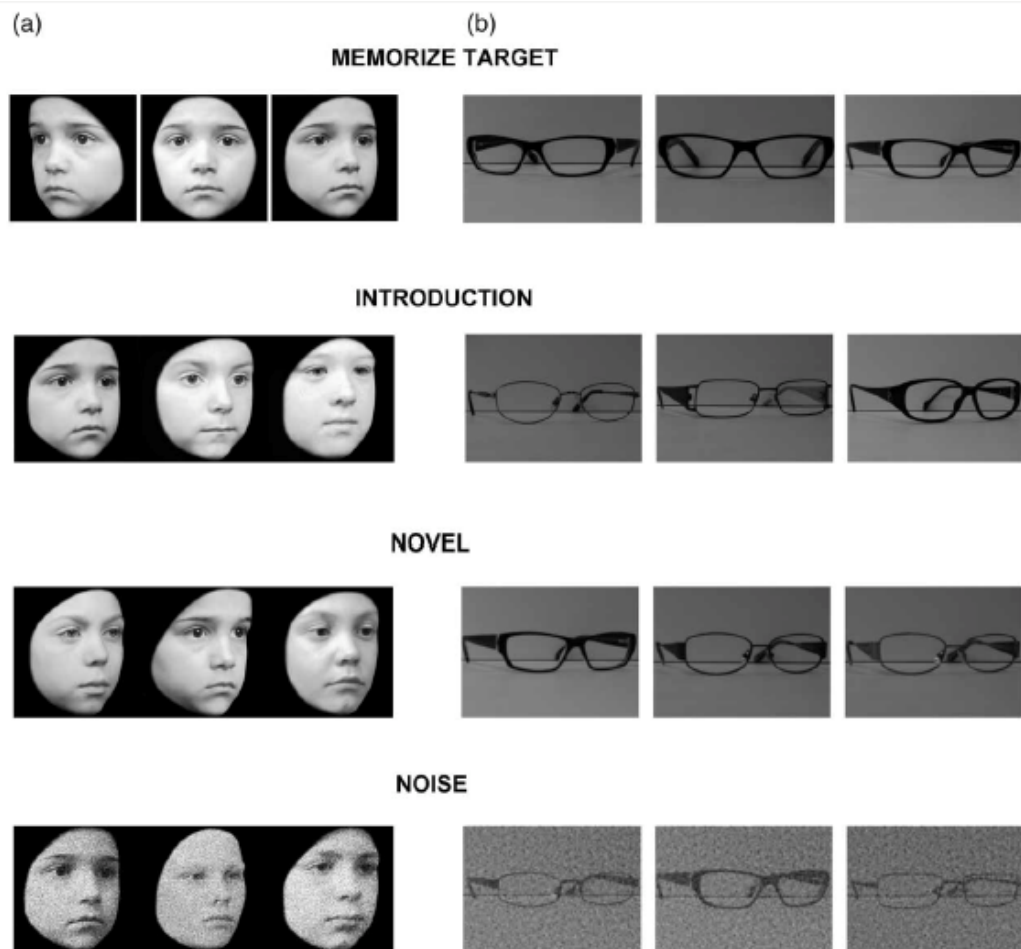


Figure 8. The CFMT-Kids and 3-Choice Object Task. (a) Example stimuli from the CFMT-kids task. (b) Example stimuli from the 3-alternative-forced-choice Object Task. Like the CFMT-C and 2-choice Object Tasks from Experiment 1, children were asked to memorize a target from three different views as is displayed in “Memorize Target.” Then, they were immediately asked to identify the target from a choice of three during the “Introduction” trials. In phase 2, they were first allowed to review all 6 of the learned



targets for 20 seconds before identifying the target from images with a “Novel” orientation. Finally, after reviewing the target images one more time (20 seconds), they were asked to identify the target from 2 distractors when the images were masked with noise. Image reprinted with permissions from Taylor &

Francis from Dalrymple et al. (2012).

The purposes of having children complete the CFMT-Kids were threefold. First and foremost, this task was recently created and, at the time that this experiment was completed, normative data had not yet been collected on a large group of children. Therefore, the inclusion of this task allowed for a direct comparison between data from this task and the widely used CFMT-C. In other words, by running both face recognition tasks on a group of children, we were able to evaluate the validity of this measure by cross-comparison with the already established CFMT-C. Second, although the central data analyses focused on examining the more widely used CFMT-C, the addition of this task allowed to possibility of asking additional questions such as whether children evaluate and recognize children’s faces differently than adult’s faces. Finally, although these analyses are not included in the scope of this thesis, inclusion of this test allowed us to compare eye-tracking of one test (e.g. CFMT-C) with face recognition scores of another (e.g. CFMT-K), reducing the possibility that significant correlations between AOIs and face recognition scores were a result of specific local qualities of the stimuli (e.g. the outline of the cropped face).

#### *Part-Whole Task – Adult Faces (PW-Adult)*

To obtain a measure of configural processing, children completed two versions of the Part-Whole task (Tanaka & Farah, 1993). As described above, the Part-Whole Task is a popular measure of global face processing and has been used with both children and

adults. In this version of the Part-Whole task, children were presented with a target face and were subsequently asked to identify one part of that target face (e.g. the eyes) either in isolation or in the context of the face. Target features included the eyes, nose, and mouth. However, the child was unaware which of the three features would be tested on a given trial. In the *PW-Adult task*, children were presented with two practice trials to be sure that they understood the rules of the game. On each trial, the participant was presented with a photo of an unfamiliar face for 3 seconds. In the whole condition, the child was immediately presented with a 2-alternative forced-choice test trial. In this trial, one of the faces was identical to the target face and the other differed only by one feature. The child was then asked to identify which face was identical to the target. The part trials were identical to whole trials with the exception that testing included two isolated features (one belonging to the target and the other not) and the child was asked to identify which of the two features belonged to the target.

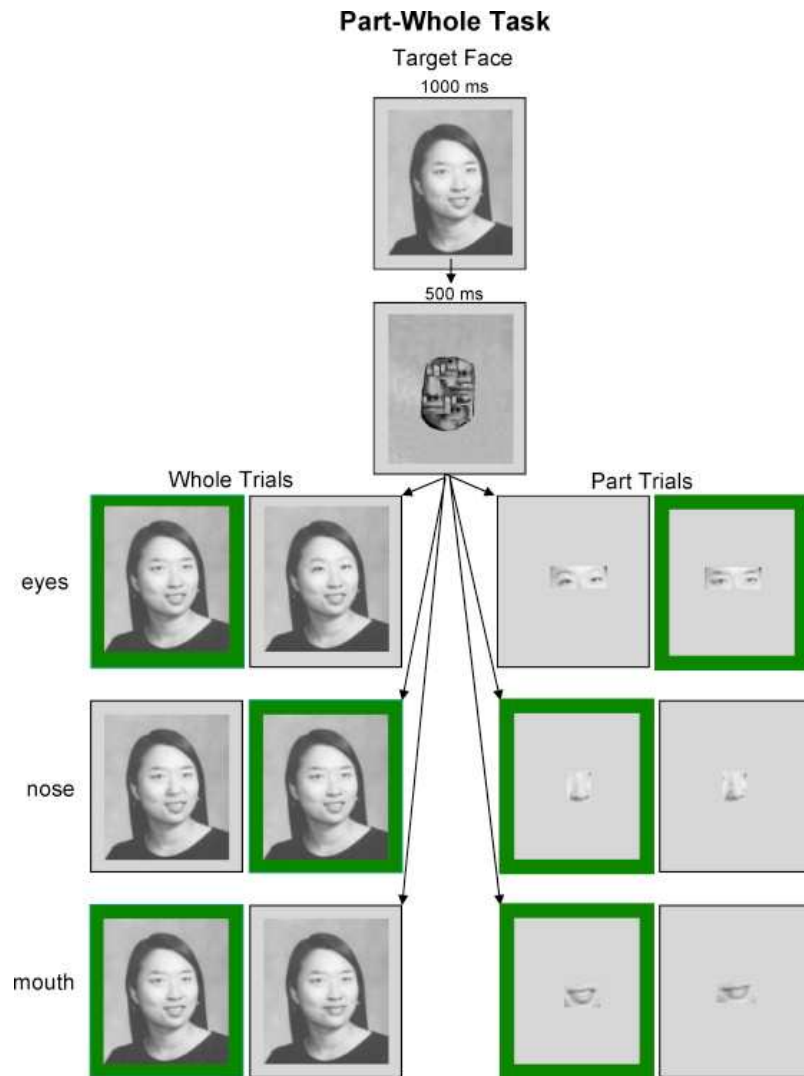


Figure 9. The Part-Whole Task – Adult Faces. First, the participant was asked to memorize a target face.

Then, in whole trials, the participant was presented with the entire face and in part trials, they were presented with only one feature. In both cases, the only difference between the two choices was the target feature itself and the participant was asked to identify the correct face or feature. Reprinted from DeGutis

et al. (2011) with permission from Elsevier.

There were several reasons for including this task. First, this specific version of the Part-Whole task, using adult faces, has not been used with children. Therefore, the

use of this task in Experiment 2 allowed for the creation of a normative data set for comparisons with future studies. Second, this task has been used in previous adult work (DeGutis, 2013; DeGutis et al., 2011). Thus, although beyond the scope of this thesis, it affords the opportunity for comparison with adult findings. Third, the use of this task, in conjunction with the *Part-Whole – Kids Faces* (see below), allows for an evaluation of whether configural processing applies to adult faces in the same way that it applies to children's faces.

#### *Part-Whole Task – Kids Faces (PW-Kids)*

Children also completed the Part-Whole Task with children's faces rather than adult faces. This test was obtained from the Let's Face It! Battery (Wolf et al., 2008) provided by James Tanaka. Like the PW – Adult Task, children were presented with a target face and were subsequently asked to identify one part of that target face (e.g. the eyes) either in isolation or in the context of the face. In the PW-Kids Task (see Figure 10), children were presented with four practice trials that depicted cartoon faces. On each trial, the participant was presented with a photo of an unfamiliar face for 4 seconds. In the whole condition, participants were immediately presented with a 2-alternative forced-choice test trial. In this trial, one of the faces was identical to the target face and the other differed only by one feature. The child was then asked to identify which face was identical to the target. The part trials were identical with the exception that testing included two isolated features (one belonging to the target and the other not) and the child was asked to identify which of the two features belonged to the target. Children had an unlimited amount of time to answer. Further details of this test are described in

Wolf et al. (2008).

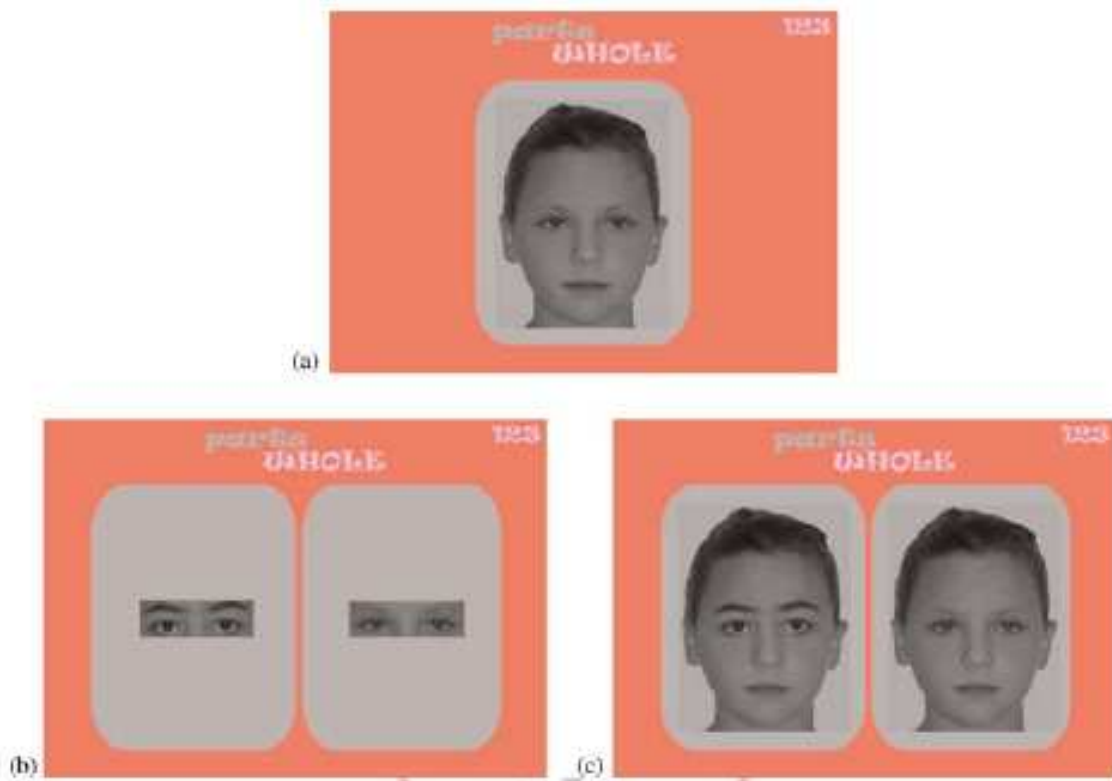


Figure 10. The Part-Whole Task – Kids. On each trial, children were first presented with a target face (a), followed by either a part trial (b) or a whole trial (c). In either case, the two choices differed by only one feature: eyes or mouth. Image reprinted with permissions from John Wiley & Sons from Wolf et al. (2008).

### *Object Task (3-Alternative Forced-Choice)*

This test was identical to the Object Task seen in Experiment 1 with the following exceptions. The test was modified to match the format of the CFMT-Kids (see Figure 8). Therefore, rather than the children learning 5 pairs of glasses, they learned 6. Similarly, on each trial, they were asked to pick the target from a line-up of 3 pairs of glasses rather than 2. Thus, with the creation of this task, we had an Object Task to match the format of each of our two face recognition tests, the 2-alternative forced-choice CFMT-C and the 3-alternative forced-choice CFMT-Kids. Using this task as a comparison allowed us to rule

out the possibility that the CFMT-Kids was too difficult for the participants to understand, given that the structure of the two tasks were identical. Furthermore, this task could be used to isolate face recognition abilities by regressing out variance explained by performance on this task from performance on the CFMT-C, as was done in Experiment 1.

### **Procedure**

Because we were interested in individual differences between children, tasks were completed in the same order for each child. After completing the consent process, children first completed tasks that required eye tracking as children needed to sit relatively still (which is easier at the beginning of an experiment than at the end). Therefore, they completed the CFMT-C followed by the CFMT-K, both of which collected eye-tracking data based on the same AOIs evaluated in Experiment 1 (with the addition of the neck region for the CFMT-C). Then, children completed the Part-Whole Tasks to examine configural processing, beginning with the PW-Adult and followed by the PW-Kids. Finally, children completed the Object task. Children were allowed to take a break between tasks if needed.

### **Results**

For all tasks, accuracy scores were calculated by dividing the number of correct responses by the number of total trials and are presented as a proportion of correct trials. All significance tests are two-tailed with a critical p-value of 0.05 unless otherwise indicated.

## **Face Recognition Tasks**

### *Cambridge Face Memory Task – Children (CFMT-C)*

As a measure of face recognition skill, each child included in the sample completed the CFMT-C (Duchaine et al., 2006). Previous studies in the Yonas Lab have found reasonable test-retest reliability for this task [ $r = 0.69$ ]. Scores were calculated as a proportion correct out of 60 trials (number correct divided by 60). As this is a 2-alternative forced-choice task, chance performance equals 0.50. Even with a much larger sample ( $n=85$ ), performance on this test was very similar to the findings from Experiment 1 [ $M = 0.72$ ,  $SD = 0.09$ ].

### *Cambridge Face Memory Task – Kids (CFMT-Kids)*

As stated above, recently, a new version of the CFMT was created for use with children. Thus, one goal of this proposal was to validate the findings of this new measure against the already popular CFMT-C. Therefore, each child who completed this task ( $n = 83$ ; 2 children were excluded for equipment failure) was given a score calculated as a proportion correct out of 72 trials (number correct divided by 72). As this is a 3-alternative forced-choice task, chance performance equals 0.33. On average, children received a score of .63 [ $SD = 0.13$ ].

### *Test Comparison: Face Recognition*

As one goal of this Experiment was to establish the validity of the CFMT–Kids, we calculated a correlation between performance on these two tasks and found that performance on the CFMT-Kids significantly correlated with performance on the CFMT-C [ $r = .528$ ,  $p < 0.001$ ].

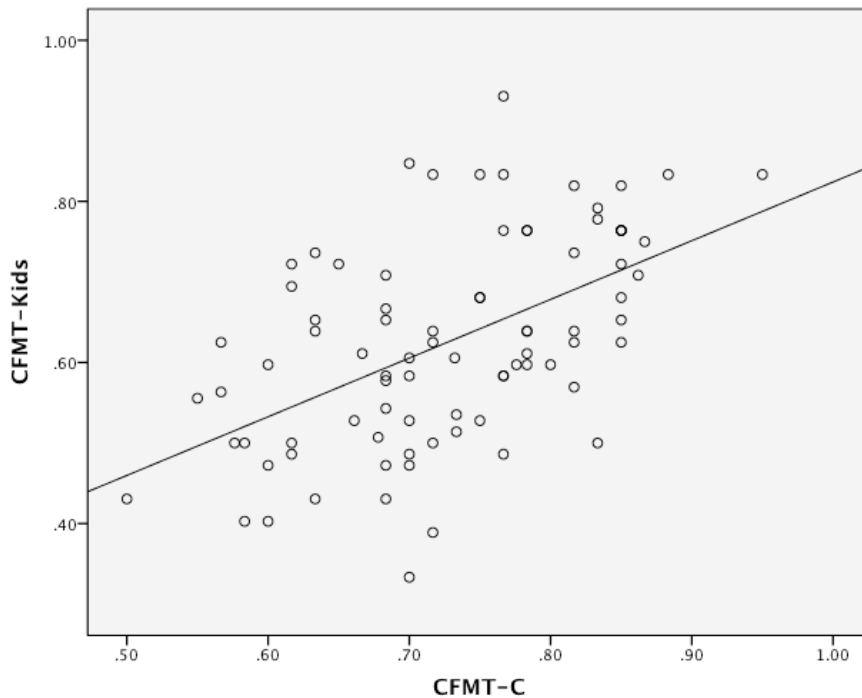


Figure 11. Correlation between CFMT-C and CFMT-Kids Scores

### **Configural Face Processing Tasks**

#### *Part-Whole Task – Adults (PW-Adult)*

As indicated above, this particular version of the Part-Whole Task has not been used with children. Thus, we were interested in the efficacy of using this particular task with children and if performance would be different between this task and the frequently used PW-Kids task (Wolf et al., 2008).

Using the Part-Whole Task, adults reliably show a whole trial advantage, with a higher proportion of correct responses on trials with the whole face present than trials showing a single feature in isolation, suggesting that adults process faces holistically (DeGutis et al., 2012). To examine these effects in children, an accuracy score was calculated for each type of trial, part and whole. Although children produced lower



accuracy than is typically seen with adults [Whole M = 0.67, SD = .10; Part M = 0.60, SD = 0.08; chance performance = .50], and despite a floor effect, children also showed a significant whole advantage [ $t(82) = 5.513, p < 0.001$ ]. These results suggest that children, like adults, use configural information to process faces. Furthermore, the whole advantage may have been reduced due to the floor effect, suggesting that this relationship is rather strong.

#### *Part-Whole Task – Kids (PW-Kids)*

The PW-Kids Task showed similar results. Again, a score was calculated for each child that reflected the number of correct trials divided by the number of total trials. As this task was created and normed for children of this age range, accuracy scores were much better as compared to the PW-Adult task (Whole M = 0.81, SD = 0.10; Part M = 0.65, SD = 0.12; chance performance = .50). Like the PW-Adult task, children once again showed a significant whole, over part, advantage [ $t(84) = 11.130, p < 0.001$ ].

#### *Test Comparison: Configural Processing*

As hypothesized, performance on the PW-Adult task significantly correlated with performance on the PW-Kids task for both the part trials [ $r = .410, p < 0.001$ ] and the whole trials [ $r = .470, p < 0.001$ ]. These data suggest that, like the PW-Kids, the PW-Adults task is effective for measuring configural face processing in children. However, given the floor effect, the use of the PW-Adult Task with younger populations should be cautioned.

## Object Task

Like the CFMT-Kids, accuracy scores were calculated for the Object Task by dividing the number of correct responses out of 72 total trials. Children achieved an average score of 0.67 (SD = 0.14; chance performance = 0.33).

As indicated above, the format of this task was identical to the CFMT-Kids with the exception that it used eyeglasses as stimuli rather than faces. Therefore, the purpose of this task was to provide a way to isolate face recognition skills, taking into account general recognition abilities. Thus, to examine the redundancy of these tasks, the relationship between performance on the face recognition tasks was compared with performance on the Object Task. Importantly, performance on the Object Task did not correlate with performance on the CFMT-Kids [ $n = 82, r = .212$ ] suggesting that these two tasks were measuring different abilities despite their similar structure. However, as in Experiment 1, this was not the case for the CFMT-C, of which performance significantly correlated with performance on the Object Task [ $n = 84, r = 0.281, p < 0.01$ ]. This is somewhat surprising given that the CFMT-C is a 2-alternative forced-choice task whereas the Object Task is 3-alternative forced-choice. Given the redundancy of these measures, further analyses examining the role of face recognition skills were evaluated in two ways: 1. As a proportion of correct trials on the CFMT (as would typically be done in the face recognition literature), and 2. As a score calculated by regressing the performance on the Object Task out of the score on the face recognition task (Wilmer, Garrido, & Herzmann, 2012). As in Experiment 1, the goal of the latter is to provide a score that isolates face recognition ability by removing variance explained

by factors directly related to the task instructions and factors related to general object recognition ability, rather than face-specific recognition ability. The number resulting from this calculation will henceforth be referred to as the Residual Face Recognition Score.

### **Selection of Data for Planned Comparisons**

The number of tasks included in this study combined with the number of AOIs from each of the eye-tracking tasks allows for an extensive number of comparisons to be made. Therefore, to limit the need of a massive correction-for-multiple comparisons and to limit the scope of this thesis, planned comparisons focused on the following:

1. Face Recognition: As a measure of face recognition, we decided to focus analyses on the CFMT-C as this measure has been used in a number of previous studies in the Yonas Lab and in other labs. Furthermore, we found that this test has a rather impressive test-retest reliability [ $r=0.69$ ], whereas the test-retest reliability of the CFMT-Kids is yet unknown. Although we expect that an investigation of the CFMT-Kids will be fruitful in the future, this task has never before been run with kids and we, therefore, are more confident about the reliability of the CFMT-C.
2. Configural Processing: Likewise, as a measure of configural processing, we decided to focus analyses on the PW-Kids as this measure has been used in a number of previous studies in other labs and has less of a floor effect in this sample. Therefore, we are more confident about the reliability of the PW-Kids as compared to the PW-Adult, which has never before been used with children.

Regardless, we hope that the PW-Adult data will be useful in the future, especially as a comparison with adult data.

3. Eye Tracking: Eye-tracking data was collected from the following AOIs: eyes, forehead, cheeks, eyebrows, nose, mouth, chin (and neck for the CFMT-C; the CFMT-Kids faces did not have a neck region). The previous literature and the data collected in Experiment 1 suggest that the eye region may be important for successful face recognition. In addition, previous literature emphasizes the distinction between the core features and the non-core features in face recognition. Therefore, in our planned comparisons, we examined the role of the eyes, the core features together (eyes, nose, and mouth), and the external features together (forehead, cheeks, chin, and neck) with the hypothesis that the eyes and core features would positively correlate with face recognition skill and possibly configural processing. Furthermore, we hypothesized that attention to the external features would negatively correlate with face recognition skill. All other non-planned analyses included a bonferonni correction for multiple-comparisons.

Therefore, in the following analyses, children needed to complete, at minimum, the CFMT-C, complete with eye tracking data, and the PW-Kids. Complete eye-tracking data was defined as at least 60% tracking (3 out of 5 seconds) on at least 66% of the learning trials from which data were collected. For the CFMT-C, this meant that children needed a minimum of 3 seconds (per trial) of tracking on 10 of the 15 learning trials in order to be included. As indicated above, only two children were excluded for limited eye tracking.

Furthermore, analyses focused on assessing each of the central hypotheses for this study. Mainly, 1) that face recognition skill would correlate with attention to the eye region or inner (eyes, nose, mouth, and eyebrows) features of the face and possibly negatively correlate with attention to the outer features of the face, 2) that face recognition skill would correlate with configural face processing and 3) that configural face processing would correlate with attention to the eye region or core/inner regions of the face.

### **Eye Tracking**

Before analyzing how eye tracking performance correlates with face recognition and configural processing, we first wanted to evaluate the amount of time that participants allocated to each area of the face during the learning trials in the face recognition task. As we were interested what information children used when learning to recognize a face, the data below summarizes the amount of time that children attended to each AOI as measured by raw looking times in seconds (Figure 12) and the proportion of total looking as measured in fixations and duration of looking time to each area of the face (Figure 13). Fixations to each area are calculated as the number of fixations to a region, divided by the total number of fixations. Duration of looking time to each area is calculated as the amount of looking time to an AOI (measured in seconds), divided by the total looking time on a given trial.

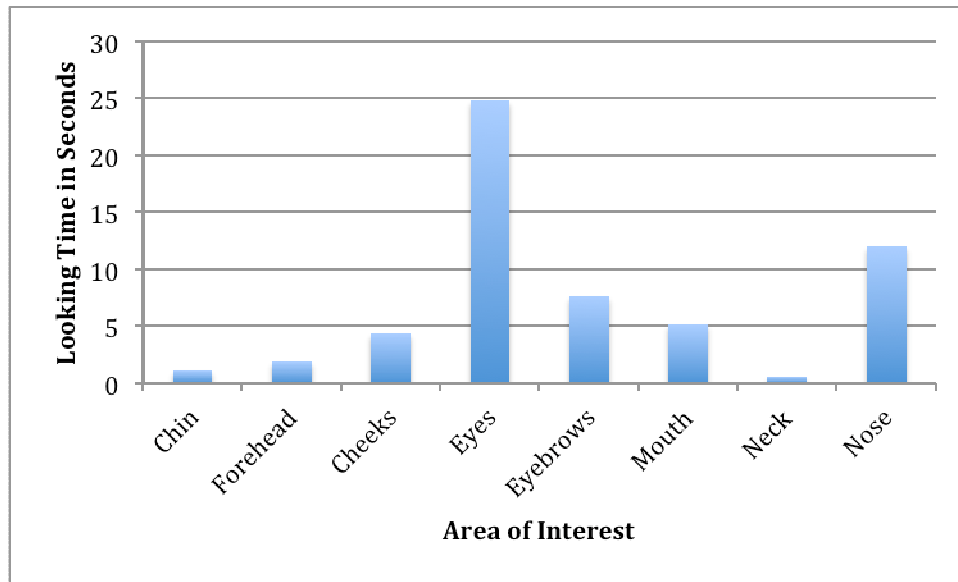


Figure 12. Average Looking Time to each AOI on the CFMT-C in Experiment 2. Children were presented with 15, 5 second trials for a total of 75 seconds of possible looking time.

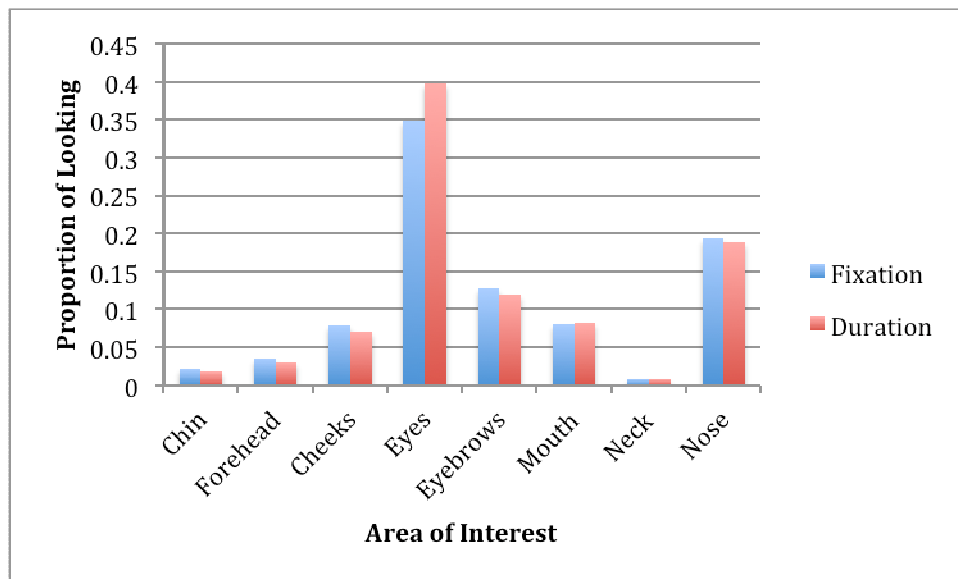


Figure 13. Proportion of Looking as measured by Fixations and Duration on the CFMT-C in Experiment 2.

As can be seen in Figures 12 and 13, children devoted the majority of their attention to the eye region, followed by the nose, eyebrows, and mouth. Interestingly, these data replicate the findings of Experiment 1 even though a different task was used to

collect eye-tracking data (CFMT-C from Experiment 2 versus the Eye Tracker Task from Experiment 1).

### **Planned Comparisons: Testing of Hypotheses**

#### *Hypothesis 1*

*Children with higher face recognition scores will spend more time and have more fixations on the eye region or inner regions of the face during face recognition tasks. Furthermore, attention to outer areas of the face such as the forehead and chin will negatively correlate with face recognition skill.*

The literature supports the notion that the inner regions of the face, namely the eyes, nose, and mouth (and perhaps eyebrows), with specific focus on the eyes, are important for successful face recognition. Therefore, we completed the following analyses to investigate these relationships.

First, we analyzed the correlation between attention to the eye region of the face and face recognition skill as measured by the CFMT-C. **The relationship between the CFMT-C score and the raw looking time (measured in seconds) was significantly correlated [ $r = 0.224$ ,  $p < 0.05$ ].** The scatterplot representing this relationship is presented in Figure 14. However, attention to the eye region did not correlate with face recognition score when measured as a proportion of fixations [ $r = 0.123$ ] or proportion of duration of looking time [ $r = 0.138$ ]. Similarly, we calculated a *Residual Face Recognition Score* by regressing performance on the Object Task out of performance on the CFMT-C in order to remove variance explained by general object recognition ability and ability to follow task

instructions. In this case, attention to the eye region did not correlate with the residual face recognition score when measured by raw looking time [ $r = .173$ ], proportion of fixations [ $r = .113$ ], or proportion of duration of looking time [ $r = .122$ ].

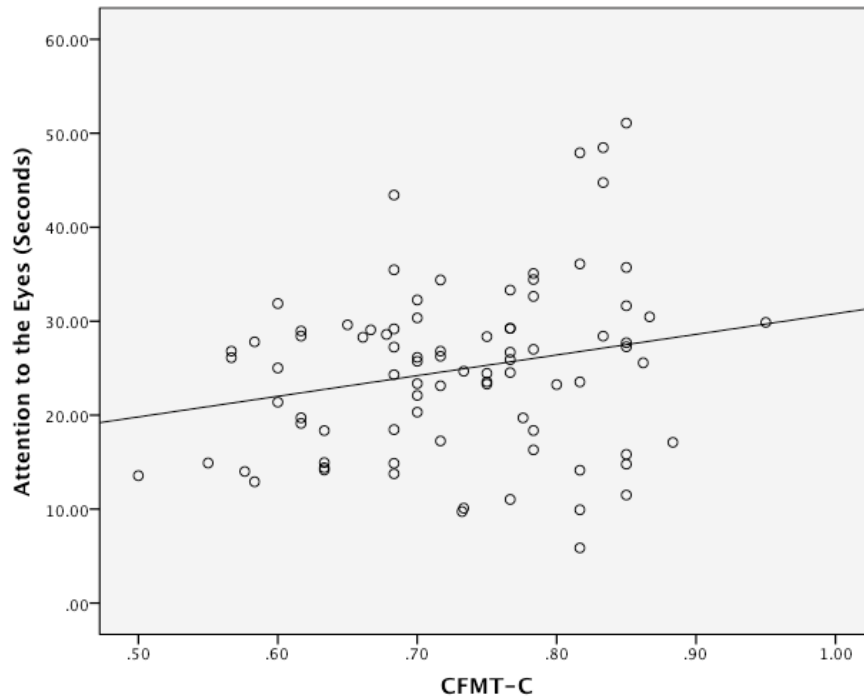


Figure 14. Correlation between Attention to the Eyes and CFMT-C Score in Experiment 2

Furthermore, we compared attention to the eyes in the highest and lowest performers on the CFMT-C when divided into quartiles. Similarly, comparisons between the two groups were not significant when measured by proportion of fixations [ $t(40) = 1.049$ ], or proportion of duration of looking time [ $t(40) = 1.092$ ]. However, when measured in raw seconds of looking time to the eye region, the difference between the two groups was marginally significant [ $t(40) = 1.738$ ,



$p=0.09$ ] with the high performers spending an average of 27.5 seconds on the eyes and the low performers spending only 21.8 seconds on the eyes.

In addition, we asked whether those with higher face recognition scores attended to the inner, core, regions of the face more than those with lower face recognition scores. Based on the previous literature and the looking time data from Experiments 1 and 2, we considered the “core” region to be the eyes, eyebrows, nose, and mouth. For each participant, we calculated the total number of seconds devoted to the inner region, the proportion of fixations to the inner region, and the proportion of duration of looking time to the inner region. However, none of these correlations were significant: raw looking time [ $r=0.096$ ], fixations [ $r=0.068$ ], and duration [ $r=0.094$ ]. This remained true when correlated with the *residual face recognition score*: raw looking time [ $r = 0.094$ ], fixations [ $r = 0.064$ ], and duration [ $r = 0.101$ ]. Similarly, a comparison of the highest and lowest performing quartiles on the CFMT-C yielded no significant differences in attention to the inner features for all three measures: raw looking time [ $t(40) = 0.516$ ], proportion of fixations [ $t(40) = 0.420$ ], and proportion of duration of looking time [ $t(40) = 0.713$ ].

Finally, based on the data from Experiment 1, we hypothesized that attention to the extraneous outer regions of the face might hinder face recognition ability. More specifically, based on the data from Experiment 1, we predicted that attention to the chin and forehead might negatively correlate with face recognition score. In addition, although the Eye Tracker Task from Experiment 1 did not include a neck region, we included the neck in the “outer” region as we believed this area would

provide little useful information for the identification of a face. Although attention to the outer features consistently showed a negative correlation with CFMT-C score, these correlations were not significant: raw looking time [ $r = -0.050$ ], proportion of fixations [ $r = -0.063$ ], and proportion of duration of looking time [ $r = -0.059$ ]. Again, this remained true when the outer region was correlated with *Residual Face Recognition Score*: raw looking time [ $r = -0.047$ ], proportion of fixations [ $r = -0.062$ ], and proportion of duration of looking time [ $r = -0.059$ ]. Likewise, comparisons of attention to the outer regions of the face between the highest and lowest quartiles (based on CFMT-C) were also not significant: raw looking time [ $t(40) = 0.007$ ], percentage of fixations [ $t(40) = 0.106$ ], and percentage of duration of looking time [ $t(40) = -0.036$ ].

In sum, the only planned comparison that yielded a significant p-value when evaluating the relationship between attention to local regions of the face and the CFMT-C was the measure of raw looking time toward the eyes. However, it is possible that it is not more attention to the eyes, per se, that is important for successful face recognition but rather more looking time to the face overall. However, this hypothesis is tempered by the fact that total looking time to the face, measured in seconds, did not significantly correlate with CFMT-C score [ $r = 0.047$ ]. Therefore, the significant relationship between looking time and face recognition score seems to be specific to the eye region.

In addition to these planned comparisons, it is useful to examine which areas of the face independently correlate with face recognition score. This however,

requires a bonferroni correction for multiple comparisons (critical p-value = 0.006). With this correction, raw looking times (seconds) yielded significant correlations for the forehead [ $r = -0.306$ ,  $p < 0.006$ ] and neck [ $r = -0.353$ ,  $p < 0.006$ ]. The chin [ $r = -0.198$ ] and eyes [ $r = 0.224$ ] were significant at the  $p < 0.05$  level. These data support the findings from Experiment 1 that the eyes positively correlated with face recognition and the forehead and chin negatively correlated with face recognition. In other words, it the significant positive correlation for the eye region, along with negative correlations for the forehead and neck support the hypothesis that the eyes are particularly important for face recognition whereas attention to the more extraneous parts of the face may interfere with successful face recognition.

#### *Hypothesis 2*

*Children who show a greater degree of configural processing of faces, as measured by the Part-Whole – Kids task, will have higher face recognition scores on the CFMT-C.*

As indicated previously, global processing on the Part-Whole task is typically measured as the difference between performance on whole and part trials. However, as indicated by Wilmer, Garrido, & Herzmann (2012) the data may be better represented by using a regression method to statistically remove the variance explained by the part trials from the whole trials. Doing so provides a direct measure of configural processing. Therefore, like DeGutis et al. (2013), we used both a subtraction and regression method to evaluate configural processing, for comparison purposes. Similarly, as in Experiment 1 and Hypothesis 1 of

Experiment 2, we used the same method with the CFMT-C and Object Task in order to isolate recognition performance specific to faces.

As predicted by DeGutis et al. (2013) and Wilmer et al. (2012), the subtraction method (whole trial performance minus part trial performance) was not sensitive enough to uncover a relationship between configural processing (PW-Kids) and face recognition score [ $r = -0.123$ ]. However, as seen in Figure 15, when using the recommended regression method, CFMT-C scores positively correlated with configural processing [ $r = 0.404, p < 0.001$ ]. This relationship remained when correlating the Residual Face Recognition Score with the Residual Part-Whole Task Score [ $r = 0.338, p < 0.01$ ]. These results suggest that those who utilize configural information while learning a face are better able to recognize faces than those who do not. It also supports the use of the regression method in isolating an advantage for whole trials in the PW-Kids Task and face-specific recognition ability in the CFMT-C.

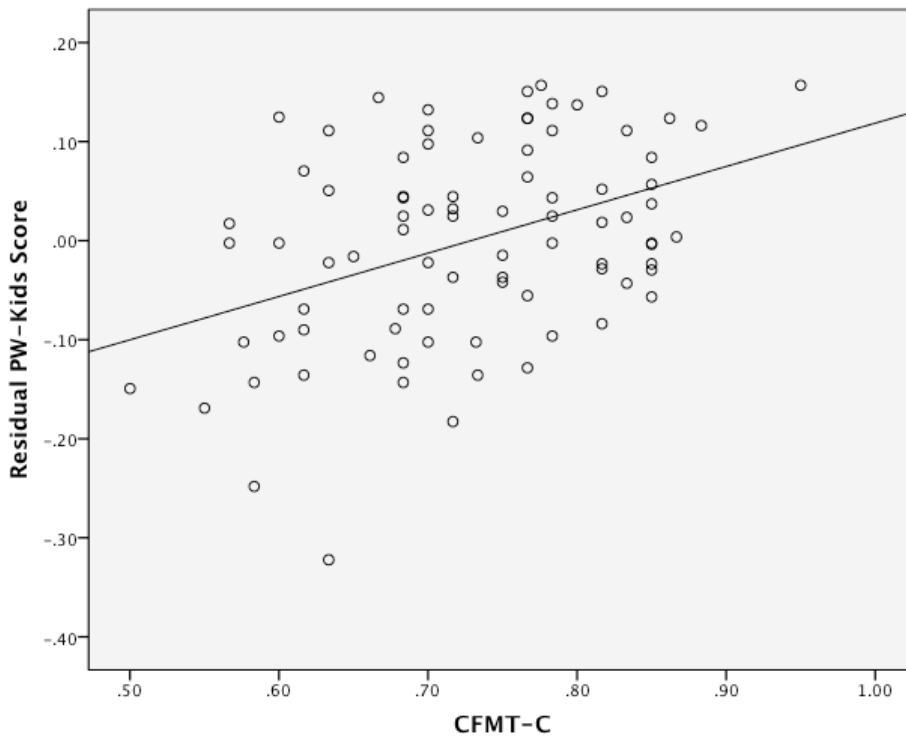


Figure 15. Correlation between CFMT-C Score and Configural Processing in Experiment 2. Residual PW-Kids Scores are calculated by regression the part-trial performance out of whole-trial performance on the PW-Kids Task. The remaining residual represents the variance unexplained by part-trials.

### *Hypothesis 3*

*Children who show a greater degree of global processing of faces will show more fixations to the eye region on eye tracking tasks.*

Finally, we wanted to examine the individual contributions of attention to the eye region and configural processing. It is possible that particular areas of the face may provide more configural information than other areas. More specifically, it is possible that the eye region is important for the calculation of relational information between features, relative to other features, especially for Caucasian Westerners (Blais et al., 2008). Therefore, the eye region may have more diagnostic value in

identifying a face when using configural information. To evaluate this hypothesis we examined the relationship between attention to the eyes on the CFMT-C and configural processing. Again, to obtain a measure of configural processing, a score was calculated for each child by isolating the variance explained by the whole trials after regressing out the part trials, their Residual PW-Kids Scores. Thus, their score reflected the residual left after removing all part-trial variance.

Again, as predicted by Wilmer et al. (2012), a subtraction method for isolating configural processing was not sensitive enough to detect a relationship between configural processing and attention to the eye region: raw looking time [ $r = 0.021$ ], proportion of fixations [ $r = 0.059$ ], and proportion of duration of looking time [ $r = -0.004$ ]. However, the Residual PW-Kids score, using the regression method, was significantly correlated with attention to the eyes on the CFMT-C as measured by raw looking time (in seconds) [ $r = 0.239, p < 0.05$ ], but not as measured by percentage of fixations [ $r = 0.168$ ] or percentage of duration of looking time [ $r = 0.163$ ]. Again, it is reasonable to believe that children who demonstrate a greater degree of configural processing are likely to look at the face longer overall, thus resulting in longer looking times toward the eyes as well. However, this hypothesis is tempered by the lack of correlation between the Residual PW-Kids Score and the total duration of attention to the face [ $r = 0.001$ ]. Therefore, it seems likely that longer duration of looking to the eye region of the face specifically is indeed associated with a greater degree of configural processing.

Furthermore, we were interested in the individual contributions of attention to the eye region and configural processing. To assess this relationship, multiple regression was used to test if configural (PW-Kids) and feature-based (attention to the eyes) processing predicted CFMT-C scores. The results of the regression indicated the two predictors significantly predicted face recognition score [ $R^2 = 0.18$ ,  $F(2, 82) = 9.02$ ,  $p < 0.001$ ]. More specifically, it was found that configural processing, as measured by the PW-Kids task, significantly predicted face recognition score [ $\beta = 3.61$ ,  $p < 0.001$ ], but attention to the eyes did not. The same model was run with Residual Face Recognition Score as the dependent variable. The model was again significant [ $R^2 = 0.12$ ,  $F(2, 81) = 5.66$ ,  $p < 0.01$ ] with configural processing significantly predicting face recognition score [ $\beta = 0.315$ ,  $p < 0.01$ ], but not attention to the eyes.

## Discussion

Experiment 2 posed three hypotheses that together examined the relationship between face recognition skill, configural processing of faces, and attention to individual areas of the face. These hypotheses were formulated based on two themes in the literature regarding what information is used for successful face recognition—namely, attention to the eye region and attention to configural properties of the face.

First, we hypothesized that attention to the eye region and core features of the face would positively correlate with face recognition skills while attention to the more extraneous outer features of the face would negatively correlate with face recognition skill. Attention to the eye region did indeed correlate with face recognition, albeit only

when measured in raw looking time (seconds) rather than percentages of fixation or duration of looking. Therefore, it is likely that 1) this relationship is rather weak and 2) converting looking times to a percentage removed some informative variance in looking behavior between children, and examining raw looking time may be a better indicator of how attention to various regions of the face influences face recognition. Furthermore, although an examination of attention to the inner (combined eyes, eyebrows, mouth, and nose) and outer (combined forehead, chin, and neck) features did not correlate with face recognition skill, analyses of individual areas yielded a few interesting findings. Correcting for multiple comparisons, attention to both the forehead and neck yielded a significant negative correlation with face recognition score. Together, these results suggest that the eye region may be particularly important for successful face recognition. Furthermore, greater attention to particular outer features of the face, such as the forehead and neck regions, may actually hinder face recognition ability. These results support the data from Experiment 1 and the general theory that the eye region is important for successful face recognition. On the other hand, these data do not support the findings from (Yang et al., 2012), who found that attention to the eye region negatively correlated with face recognition skill. However, their data was collected with a Chinese population and may not reflect the same attentional processes used in Western Caucasian populations.

Second, we hypothesized that scores of configural processing would significantly correlate with face recognition skill in children. This hypothesis is important because, until recently, this theory has been widely supported but not empirically tested. Only



recently has the relationship between configural processing and face recognition been demonstrated in adults via the investigation of individual differences (DeGutis et al., 2013; Richler et al., 2011; Wang et al., 2012). Our data supported these findings by showing that regression-based scores of configural processing significantly correlated with face recognition scores of children when measured by the CFMT-C and the PW-Kids task.

Finally, despite the rather distinct theories that configural processing and attention to particular features may influence successful face recognition, we hypothesized that local and configural information might not be mutually exclusive. This is supported by evidence that some measures of configural processing seem to be more affected by particular local regions. For example, the inversion effect, typically thought to be a measure of configural processing, is at least in part dependent on local features, specifically the eye region (Leder & Bruce, 2000; Leder et al., 2001). Therefore, we hypothesized that measures of configural processing would correlate with attention to the eye region, providing evidence that the eye region, in particular, is used in configural processing. Indeed, we found that children who spent more time looking at the eyes were more likely to show a greater degree of configural processing as measured by the PW-Kids task. However, when both PW-Kids scores and attention to the eyes were entered as predictors of face recognition score, only configural processing remained a significant predictor. In other words, when controlling for variance explained by the part-whole task, the relationship between attention to the eyes and face recognition was no longer significant. This suggests that there is shared variance between attention to the eyes and

configural processing, supporting the findings in the literature that configural processing may be, in part, carried by the eye region of the face.

In addition to these findings, Experiment 2 provided valuable information regarding the efficacy of each of the measures used for evaluating face recognition. First, Experiment 2 replicated the findings of Experiment 1 in terms of 8-year-old performance on the CFMT-C, further validating the value of this test. Second, we collected data on the CFMT-Kids for the first time. The value of this new task was emphasized by the high correlations between performance on the CFMT-C and the CFMT-Kids, validating the task for future work with children of this age group. Furthermore, the CFMT-Kids data was not influenced by a ceiling or floor effect. Thus, this task may be very useful in the future for validating face recognition skills in individual children with possible face recognition impairment. Third, although the PW-Adult task produced a fairly substantial floor effect in this age group, this floor effect was not enough to abolish a significant whole, over part, advantage and performance on this measure significantly correlated with performance on the better established PW-Kids. Thus, although it is possibly not as effective as the PW-Kids task, which is influenced by less of a floor effect and more child-friendly, the PW-Adult task is still effective for examining configural processing in children. Finally, Experiment 2 provided data on the 3-alternative forced-choice version of the Object Task. With no ceiling or floor effect and a nice distribution of scores, this task will be useful as a comparison with the 3-alternative forced-choice CFMT-Kids Task.

In sum, the findings of this study are important in that they, for the first time, directly examine how global information and the eye region of the face are related to the ability to identify faces in children. Understanding how these individual differences between typically developing children are related to face recognition is important to the field in several ways. First of all, it informs our understanding of the process by which children are able to recognize faces and the information that is most essential for this process. Second, it provides an opportunity to isolate the aspects of face recognition that may be impaired in cases of children who experience difficulty with face recognition. By isolating these variables, we may be able to successfully train adaptive face recognition strategies by encouraging children to attend to the relevant features of the face.

## **CHAPTER 4: Experiment 3**

### **Introduction**

In an effort to replicate the findings of Experiment 2, Experiment 3 again measured face recognition skill, with eye tracking, and configural face processing in a group of children. The Experiment 2 sample may not have provided enough of a polarized group to detect subtle relationships between configural processing, attention to local features, and face recognition in children. Even with a sample of 85 children and a clear range of face recognition scores as in Experiment 2, it is possible that a more polarized range of face recognition abilities would further elucidate the differences between successful face recognizers and poor face recognizers. To maximize our ability to detect individual differences on these tasks, we pre-selected children from a list of those who had already participated in studies in our lab and chose children based on their

unusually high or unusually low CFMT-C scores, henceforth referred to as *high performers* and *low performers*. This allowed us to compare the two groups (high performers and low performers) in order to replicate findings from Experiments 1 and 2 using a wider age range and wider range of face recognition abilities.

The goals and hypotheses of Experiment 3 were identical to that of Experiment 2 (see Table 1). However, we added one additional hypothesis. To date, there has been very little investigation of the social effects of face recognition skill. Only two studies have been published examining the hypothesis that face recognition abilities affect social development. The first is a study examining the social consequences of DP in adults. In this study, adults with DP completed a semi-structured interview asking about their life experiences and how their face recognition impairment affected their daily interactions with others (Yardley et al., 2008). They reported difficulties in social relationships that lead to chronic anxiety, embarrassment, and guilt. Similarly, Diaz (2008) published a description of the social consequences of DP in a single child who reported difficulty in social relationships and concerns about safety, among other things. The paucity of research on this topic is surprising considering that it is widely believed that prosopagnosia has a profound affect on the development of social skills. Therefore, to evaluate the relationship between social skills and face recognition, a selection of parents and children completed a loneliness questionnaire with the hypothesis that children with lower face recognition scores would exhibit a greater degree of loneliness than children with higher face recognition scores.

## Method

### Participants

To select participants for this experiment, we were limited by the population of children from whom we had already collected CFMT-C data in the lab. In other words, we recruited from a list of children who had already participated in our face recognition research. However, we wanted to collect as much data as possible to ensure a large enough sample size. Thus, to maximize the number of recruited high and low performers, we created a list of each cohort that had participated in face recognition research in the lab. From each list, we sorted children based on their CFMT-C score at their first testing in the lab and recruited from each age group, beginning with the top and bottom of each list, in order to obtain the most polarized samples possible. Then, selected and willing children returned to the lab for testing. In addition to the exclusion criteria used in Experiment 2 (minimum of CFMT-C score, with eye tracking data, and PW-Kids), children were excluded from analyses for two reasons: 1. If a child showed inconsistent performance on the CFMT-C for their age group, between the two testing sessions, they were excluded from the sample. We were primarily interested in the difference in looking behavior between high and low performing children. Thus, if their initial score was high but their subsequent score was either mediocre or low for their age group, they were excluded. Likewise, if their initial score was low but their subsequent score was either mediocre or high for their age group, they were excluded. However, if they received relatively consistent scores across sessions, they were included. 2. To ensure that age would not be a factor in the analysis, we recruited an aged-matched

sample, with one high performer for every low performer from each age group.

Therefore, to be included, children needed to have an age-matched counterpart. Children without an age-matched counter-part, after other exclusions, were excluded.

The final sample included 30 children (18 females) of the following age groups: 8-year-olds ( $n = 8$ ,  $M = 8;6$ , range = 8;4—8;11), 9-year-olds ( $n = 10$ ,  $M = 9;3$ , range = 9;0 – 9;5), 10-year-olds ( $n = 8$ ,  $M = 10;6$ , range = 10;3 – 10;8), and 13-year-olds ( $n = 4$ ,  $M = 13;6$ , range = 13;1 – 13;11). As in Experiment 2, children needed to have completed, at minimum, the CFMT-C with sufficient tracking data and the PW-Kids task in order to be included in the sample. Eight additional children were excluded from the sample for the following reasons: equipment failure (5), experimenter error (2), and insufficient eye tracking data (1). Furthermore, as indicated above seven children were excluded for inconsistent CFMT-C scores (6) and lack of an age-matched control after all other exclusions (1).

### **Apparatus and Stimuli**

The apparatus and stimuli from Experiment 3 were identical to that of Experiment 2.

### **Procedure**

The procedure from Experiment 3 was identical to that of Experiment 2 with one exception. A subset of participants and their parents ( $n = 25$ ) completed the *Loneliness and Social Dissatisfaction Questionnaire* (see Appendix 2; Asher, Hymel, & Renshaw, 1984). The purpose of this questionnaire was to obtain a measure of social functioning as related to loneliness in children. By collecting this information, we were able to compare

scores between the high and low performing children, based in their CFMT-C score, and thus determine if the degree of loneliness experienced by children was related to their face recognition skill. Parents and children had the option of either completing this survey in the lab or online from home after participating in the lab. Children filled out the original version of the questionnaire and parents completed a modified version of the same questions (see Appendix 2).

## **Results**

For all tasks, accuracy scores were calculated by dividing the number of correct responses by the number of total trials and are presented as a proportion of correct trials. All significance tests are two-tailed with a critical p-value of 0.05 unless otherwise indicated.

### **Face Recognition Tasks**

#### *Cambridge Face Memory Task – Children (CFMT-C)*

As a measure of face recognition skill, each child included in the sample completed the CFMT-C (Duchaine et al., 2006). Previous studies in the Yonas Lab have found reasonable test-retest reliability for this task [ $r = 0.69$ ]. To further validate this finding, test-retest reliability was again calculated with the present sample before excluding children based on their CFMT-C consistency. The correlation between the initial scores on the CFMT-C and the scores collected for Experiment 3 replicated the previous findings from this lab [ $r = 0.72$ ]. This is particularly encouraging given that, with several different cohorts of children, a variable amount of time had passed between testing sessions for each group of children, suggesting that this measure is relatively

stable across age. However, it is possible that CFMT-C scores are more consistent in children with particularly extreme scores, thus leading to the rather high test-retest reliability.

Means and standard deviations for initial and present CFMT-C scores are presented in Table 4. Given that children were pre-selected based on their CFMT-C score, we expected a significant difference between high and low performers in these measures. Overall, CFMT-C scores significantly differed between high and low performers both when comparing their initial score [ $t(28) = 11.536, p < 0.001$ ] and when comparing their present scores [ $t(28) = 8.458, p < 0.001$ ].

	Initial CFMT-C Score	Present CFMT-C Score
High Performers	M = 0.89, SD = 0.05	M = 0.91, SD = 0.05
Low Performers	M = 0.62, SD = 0.02	M = 0.69, SD = 0.09

Table 4. CFMT-C Scores for High and Low Performers. Scores represent their initial CFMT-C and their score during the present experiment.

#### *Cambridge Face Memory Task – Kids (CFMT-Kids)*

As stated in Experiment 2, one goal of this proposal was to validate the findings of CFMT-Kids against the already popular CFMT-C. As in Experiment 2, performance on the CFMT-Kids significantly correlated with performance on the CFMT-C [ $r = 0.818, p < 0.001$ ]. A scatterplot representing the correlation between CFMT-C scores and CFMT-Kids scores is presented in Figure 16. Furthermore, for each child who completed this task ( $n = 29$ ; 1 child was excluded for equipment failure) we compared scores between the high and low performers (based on their CFMT-C scores). Overall, high performers [ $M = 0.82, SD = 0.11$ ] produced significantly higher CFMT-Kids scores than



low performers [ $M = .54$ ,  $SD = 0.14$ ], suggesting that these two tests are likely measuring the same qualities of face recognition [ $t(27) = 5.89$ ,  $p < 0.001$ ].

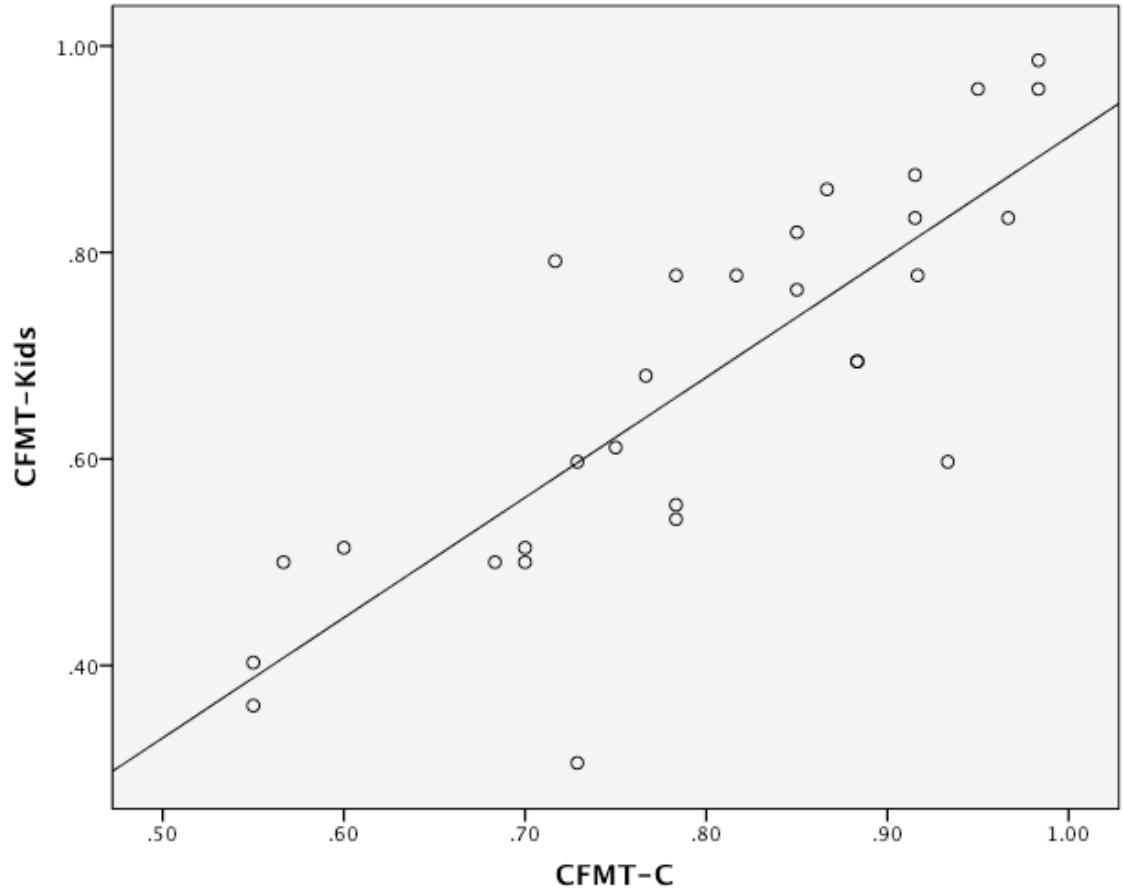


Figure 16. Correlation between CFMT-C and CFMT-Kids Scores in Experiment 3.

### Object Recognition

As indicated in Experiment 2, the format of this task was similar to the CFMT-C with the exception that it used eyeglasses as stimuli rather than faces. Because we were mainly interested in children's face recognition abilities, we wanted to confirm that low scores on the CFMT-C were reflective of impaired face recognition rather than impaired object recognition more generally. Thus, we examined the object recognition abilities of both high and low performers.

Performance on the object task significantly differed between high [ $M = 0.82$ ,  $SD = 0.07$ ] and low performers [ $M = 0.69$ ,  $SD = 0.11$ ], with high performers exhibiting significantly better object recognition scores than their low-performing counterparts [ $t(28) = 3.63$ ,  $p < 0.001$ ]. Likewise, CFMT-C scores significantly correlated with Object Task scores [ $r = 0.429$ ,  $p < 0.05$ ].

Given the redundancy of these measures, further analyses examining the role of face recognition skills were evaluated in two ways as in Experiment 2: 1. As a proportion of correct trials on the CFMT (as would typically be done in the face recognition literature), and 2. As a score calculated by regressing the performance on the Object Task out of the score on the face recognition task (Wilmer, Garrido, & Herzmann, 2012). As in Experiments 1 and 2, the goal of the latter is to provide a score that isolates face recognition ability by removing variance explained by factors directly related to the task instructions and factors related to general object recognition ability, rather than face-specific recognition ability. This score is henceforth referred to as the *Residual Face Recognition score*.

### **Selection of Data for Planned Comparisons**

The number of tasks included in this study combined with the number of AOIs from each of the eye-tracking tasks allows for an extensive number of comparisons to be made. Therefore, to limit the need of a large correction-for-multiple comparisons and to limit the scope of this thesis, we evaluated the data as in Experiment 2. In other words, we conducted planned comparisons that focused on the CFMT-C, along with the corresponding eye-tracking data, the PW-Kids.

Furthermore, analyses focused on assessing each of the central hypotheses for this study. Mainly, 1) that face recognition skill would be predicted by attention to the eye region or inner (eyes, nose, mouth, and eyebrows) features of the face, 2) that face recognition skill would be predicted by configural face processing and 3) that configural face processing would be predicted by attention to the eye region or core/inner regions of the face.

### **Planned Comparisons: Testing of Hypotheses**

#### *Hypothesis 1*

*Children with higher face recognition scores will spend more time and have more fixations on the eye region or inner regions of the face during face recognition tasks. Conversely, children with lower face recognition skills will devote more attention to outer areas of the face such as the forehead and chin.*

To examine the relationship between face recognition skill and attention to the eye region, we first analyzed the correlation between attention to the eye region of the face and face recognition skill as measured by the CFMT-C. Interestingly, the relationship between the CFMT-C score and both the raw looking time [ $r = 0.617$ ,  $p < 0.001$ ; see Figure 17] and proportion of duration of looking time [ $r = 0.59$ ,  $p < 0.01$ ] were significantly correlated. Only when measured as a proportion of fixations did attention to the eye region not correlate with face recognition score [ $r = 0.166$ ]. However, once again, it is possible that those who looked longer at the eye region simply looked longer at the face in general, thus explaining their better face recognition ability. However, this alternative explanation was again tempered by

the fact that the amount of time spent looking at the face, overall, did not correlate with the CFMT-C score [ $r = 0.335$ ].

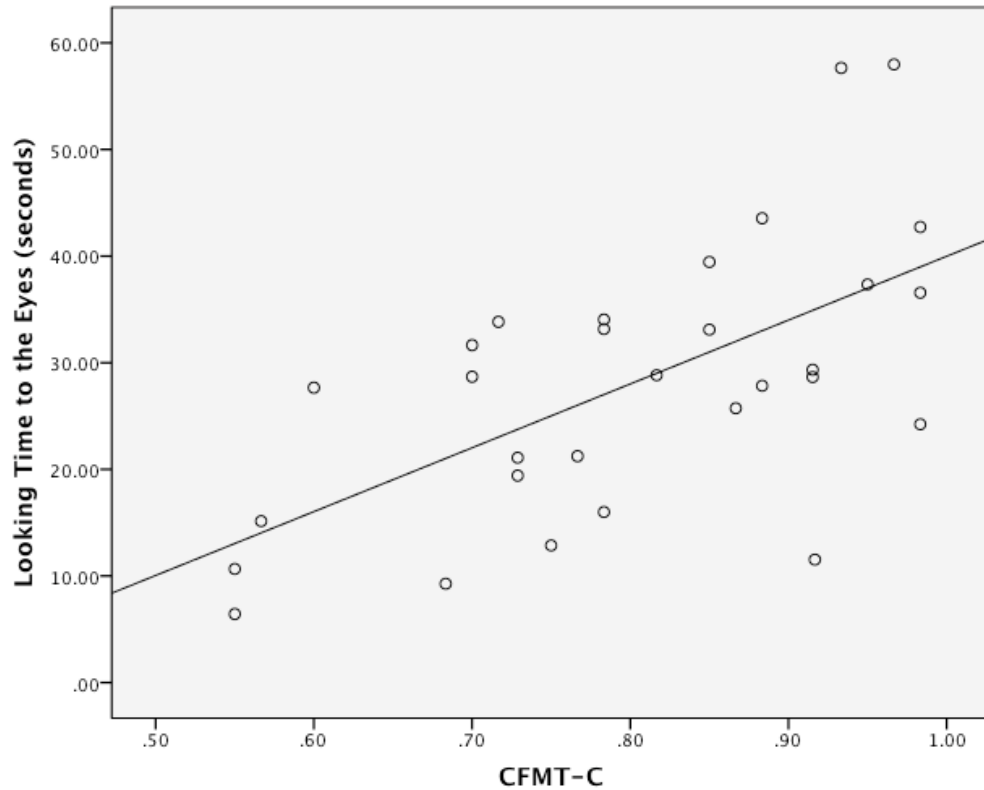


Figure 17. Correlation between CFMT-C Scores and Attention to the Eye Region in Experiment 3.

Similarly, we calculated a *Residual Face Recognition Score* by regressing performance on the Object Task out of performance on the CFMT-C in order to remove variance explained by general object recognition ability and ability to follow task instructions. The relationship between Residual Face Recognition score and both the raw looking time [ $r = 0.581, p < 0.001$ ] and proportion of duration of looking time [ $r = 0.550, p < 0.01$ ] were significantly correlated. Again, attention to the eye region did not correlate with the Residual Face Recognition score when measured as a proportion of fixations [ $r = 0.135$ ].

Furthermore, similar to the quartile comparisons from Experiment 2, we directly compared attention to the eyes between the high and low performers based on their CFMT-C score. Once again, although there were no differences between groups when measured as a proportion of fixations to the eyes [ $t(28) = 1.629$ ], both raw looking times [ $t(28) = 3.369, p < 0.001$ ] and proportion of duration of looking time [ $t(28) = 3.566, p < 0.001$ ] were significantly different between groups.

According to our hypotheses, we also asked whether those with higher face recognition scores attended to the inner, core, regions of the face more than those with lower face recognition scores. As in Experiment 2, we considered the “core” region to be the eyes, eyebrows, nose, and mouth. For each participant, we calculated the total number of seconds devoted to the inner region, the proportion of fixations to the inner region, and the proportion of duration of looking time to the inner region. Similar to the eye region analysis, CFMT-C scores significantly correlated with attention to the inner region when measured in raw looking time [ $r = 0.621, p < 0.001$ ] and proportion of duration of looking [ $r = 0.611, p < 0.001$ ] but not proportion of fixations [ $r = -0.064$ ]. These relationships remained even after regressing out variance explained by object recognition through an examination of Residual Face Recognition scores: raw looking time [ $r = 0.543, p < 0.01$ ], proportion of fixations [ $r = 0.611, ns$ ], and proportion of duration of looking [ $r = 0.502, p < 0.01$ ].

Likewise, a comparison between the high performers and low performers yielded similar findings with high performers attending to the inner features of the

face more than low performers when measured in raw looking time [ $t(28) = 2.712, p < 0.05$ ] and proportion of duration of looking [ $t(28) = 3.445, p < 0.01$ ], but not proportion of fixations [ $t(28) = 0.538$ ].

Finally, we hypothesized that low performers would attend to the outer (chin, forehead, and neck) regions of the face more than high performers. This hypothesis was supported by examining the correlation between the CFMT-C and attention to the outer region with significant correlations for raw looking times [ $r = -0.496, p < 0.01$ ] and the proportion of duration of looking [ $r = -0.579, p < 0.001$ ], but not proportion of fixations [ $r = -0.099$ ]. These relationships remained when examining the correlation between Residual Face Recognition scores and attention to the outer region: raw looking times [ $r = -0.528, p < 0.01$ ], proportion of fixations [ $r = -0.101, ns$ ], and proportion of duration of looking [ $r = -0.605, p < 0.001$ ].

Likewise, we compared performance between the high and low performers with the hypothesis that the low performers would attend more to the outer features than high performers. Once again, this hypothesis was supported when measured in raw looking time [ $t(28) = -2.254, p < 0.05$ ] and proportion of duration of looking [ $t(28) = -2.510, p < 0.05$ ], but not proportion of fixations [ $t(28) = -0.793$ ].

In sum, all of the planned comparisons examining the relationship between attention to local regions of the face and face recognition skills were significant when measured by raw looking times and the proportion of duration of looking. However, none of the examinations of proportion of fixations were significant. This is further discussed in the discussion of this section.

In addition to these planned comparisons, it is useful to examine which areas of the face independently correlate with face recognition score. This however, requires a bonferroni correction for multiple comparisons (critical p-value = 0.006). With this correction, raw looking times (seconds) yielded significant correlations for only the eye region [ $r = 0.617$ ,  $p < 0.001$ ]. All correlations and p-values are presented in Table 5.

	Chin	Forehead	Cheeks	Eyes	Eyebrows	Mouth	Neck	Nose
<i>r</i>	-.383	-.346	-.449	.617	.030	-.149	-.433	-.068
<i>p</i>	.036	.061	.013	.000	.875	.433	.017	.719

Table 5. Correlations between CFMT-C Score and each AOI in Experiment 3. Attention to the eyes was measured by raw looking time in seconds. Critical p-value = 0.006.

Attention to different areas of the face were also examined by comparing the high and low performing children. Raw looking times to each area, for each group, are presented in Figure 18. A bonferroni correction was made for multiple-comparisons, resulting in a critical p-value of 0.006. In this case, only eye region [ $t(28) = 3.369$ ,  $p < 0.006$ ] and the cheek regions [ $t(28) = -2.973$ ,  $p < 0.006$ ] yielded significant differences between groups with high performers spending more time on the eye region and less time on the cheek region than low performers. All other comparisons were not significant with the corrected p-value.

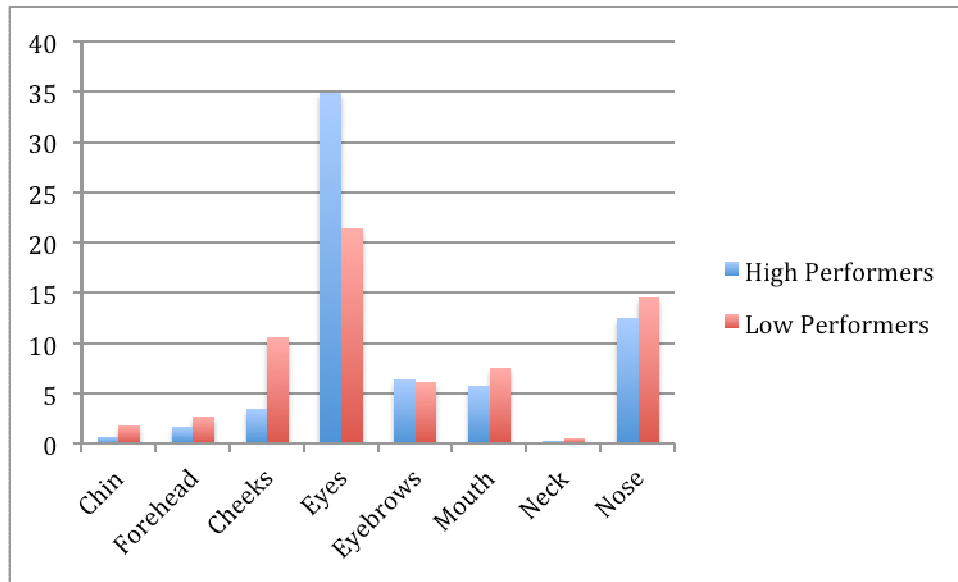


Figure 18. Raw Looking Times (in seconds) for each AOI for High and Low Performers.

Finally, to visualize the looking patterns of each age group, Figure 19 shows a heat map highlighting the areas most attended to for each group. Red areas indicate regions in which children devoted the most attention, followed by yellow and green. These maps demonstrate that the high performing children attended more to the core, inner, regions of the face, especially the eyes, whereas the low performers looking patterns were more variable with a much greater degree of attention to the non-core regions of the face relative to their age-matched counterparts.



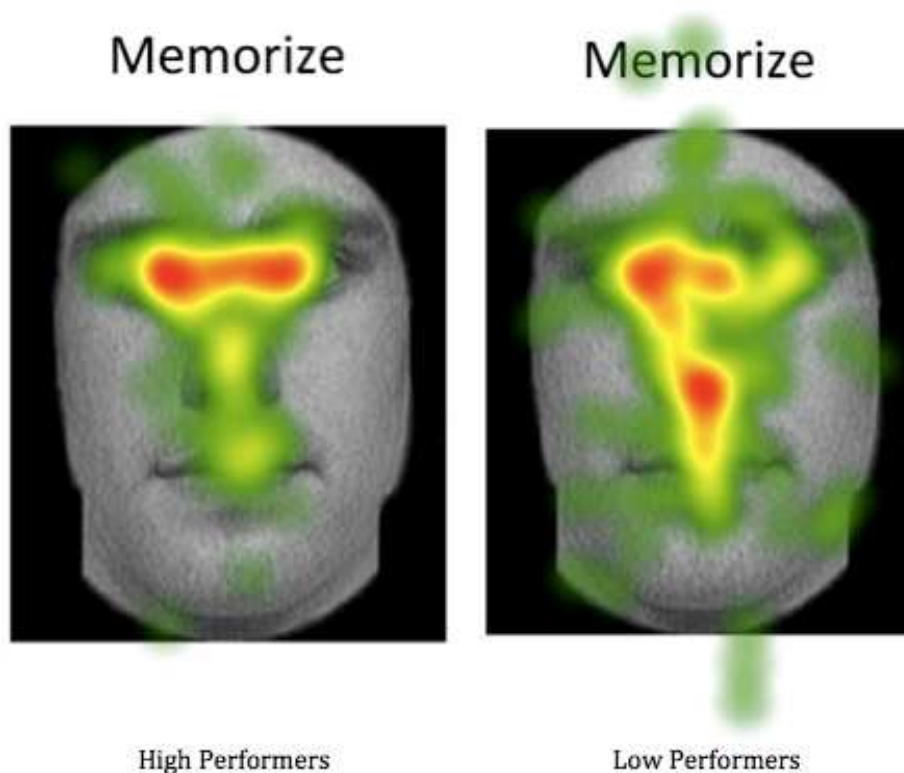


Figure 19. Heat Map of Looking Behavior for High and Low Performers on the CFMT-C.

### *Hypothesis 2*

*Children who show a greater degree of configural processing of faces, as measured by the Part-Whole – Kids task, will have higher face recognition scores on the CFMT-C.*

The means for high and low performers in the PW-Kids task are presented in Figure 20. To compare groups, a 2 (group: high performers and low performers) x 2 (trial type: part trials versus low trials) mixed ANOVA was conducted with trial type as the between-subjects factor and PW-Kid accuracy scores as the dependent variable. There was a significant main effect of both group [ $F(1, 28) = 30.318, p < 0.001$ ] and trial type [ $F(1, 28) = 28.184, p < 0.001$ ], but no interaction. As can be

seen in Figure 20, both high and low performers produced a significant whole advantage, with high performers obtaining higher accuracy scores than low performers.

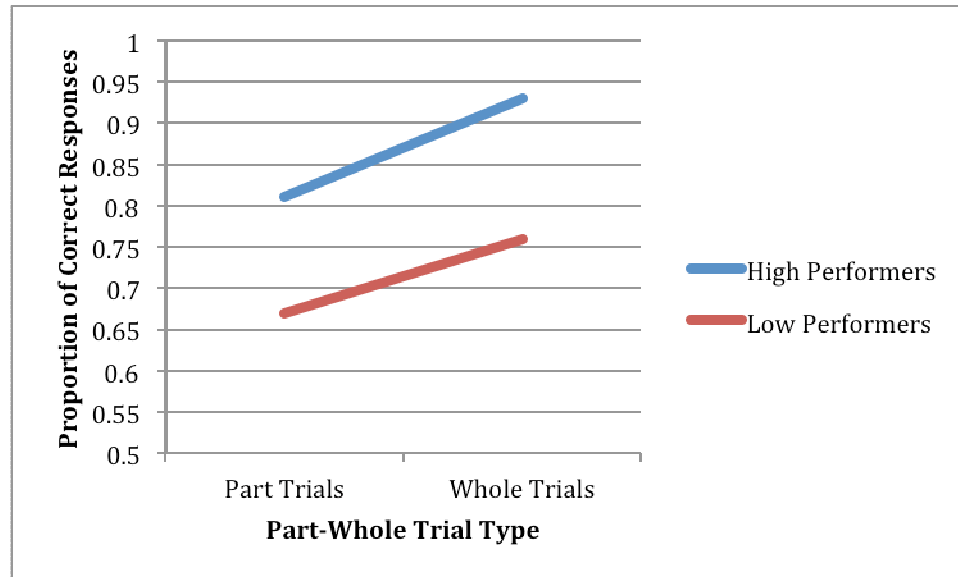


Figure 20. Accuracy scores of high and low performers on the PW-Kids task.

However, this analysis is akin to using subtraction scores to evaluate a whole advantage. Thus, we also used the regression method to evaluate configural processing. In addition, as in Experiments 1 and 2, we used the same method with the CFMT-C and Object Task in order to isolate recognition performance specific to faces.

As predicted by DeGutis et al. (2013) and Wilmer et al. (2012), the subtraction method (whole trial performance minus part trial performance) was not sensitive enough to uncover the relationship between configural processing (PW-Kids) and face recognition score [ $r = 0.026$ ]. However, when using the recommended regression method, CFMT-C scores showed a marginally significant

correlation with configural processing [ $r = 0.335, p = 0.071$ ]. However, this relationship did not remain when correlating the Residual Face Recognition Score with the Residual Part-Whole Task Score [ $r = 0.154, ns$ ]. The implications of this are discussed in the discussion of this section.

In addition, we directly compared configural processing differences between the high and low performers. When measured using the Residual Part-Whole Task score, high performers showed greater evidence of configural processing than low performers [ $t(28) = 2.434, p < 0.05$ ].

These results suggest that those who utilize configural information while learning a face are better able to recognize faces than those who do not. It also supports the use of the regression method in isolating an advantage for whole trials in the PW-Kids Task.

### *Hypothesis 3*

*Children who show a greater degree of global processing of faces will show more fixations to the eye region on eye tracking tasks.*

Although the separation of high and low performers does not directly pertain to this hypothesis as testing of this hypothesis does not include face recognition score, this data provides the opportunity to replicate the findings of Experiment 2.

Once again, we suspected that particular areas of the face may provide more configural information than other areas. More specifically, it is possible that the eye region is important for the calculation of relational information between features, relative to other features, especially for Caucasian Westerners (Blais et al., 2008).

Therefore, the eye region may have more diagnostic value in identifying a face when using configural information. To evaluate this hypothesis we examined the relationship between attention to the eyes on the CFMT-C and configural processing as measured by the Residual Part-Whole Score.

In this case, neither the subtraction method nor the regression method revealed a significant correlation between configural processing of faces and attention to the eye region. Subtraction Method: raw looking time [ $r = -0.228$ ], proportion of fixations [ $r = -0.129$ ], and proportion of duration of looking time [ $r = -0.035$ ]. Regression Method: raw looking time [ $r = -0.004$ ], proportion of fixations [ $r = -0.129$ ], and proportion of duration of looking time [ $r = -0.009$ ].

Furthermore, we were interested in the individual contributions of attention to the eye region and configural processing. To assess this relationship, multiple regression was used to test if configural (PW-Kids) and feature-based (attention to the eyes) processing predicted CFMT-C scores. The results of the regression indicated the two predictors significantly predicted face recognition score [ $R^2 = 0.494$ ,  $F(2, 27) = 13.165$ ,  $p < 0.001$ ]. More specifically, it was found that both configural processing, as measured by the PW-Kids task [ $\beta = 2.46$ ,  $p < 0.05$ ] and attention to the eyes (measured in seconds) [ $\beta = 4.512$ ,  $p < 0.001$ ] significantly predicted face recognition score. The same model was run with Residual Face Recognition Score as the dependent variable. The model was again significant [ $R^2 = 0.362$ ,  $F(2, 27) = 7.658$ ,  $p < 0.01$ ] with attention to the eyes significantly predicting face recognition score [ $\beta = 3.784$ ,  $p < 0.001$ ], but not configural processing.

#### *Hypothesis 4*

*Children with low face recognition scores will experience a greater degree of loneliness as measured by the Loneliness and Social Dissatisfaction Questionnaire (see Appendix 2; Asher et al., 1984) than children with high face recognition score.*

To assess the degree to which children with high and low face recognition skills were able to develop and maintain social friendships, children filled out the Loneliness and Social Dissatisfaction Questionnaire. In addition, parents completed an adapted version of this questionnaire, answering the same questions about their children. Scoring information for this questionnaire is included in Appendix 2.

Despite reports in the literature that children and adults with DP experience social difficulties, the present hypothesis was not supported. For both children and adults, questionnaire results did not correlate with CFMT-C scores or Residual Face Recognition scores. Similarly, t-tests comparing the high and low performers on questionnaire outcomes were not significant. The implications and alternative explanations for this finding are included in the discussion for this section.

### **Discussion**

The goal of Experiment 3 was to replicate the results of Experiment 2 with a more polarized sample of children; those with high face recognition scores on the CFMT-C and those with low face recognition scores on the CFMT-C. We recruited children previously tested in the lab, based on their initial face recognition score and classified them as either high or low performers. Choosing two groups that differed so dramatically in their face recognition ability allowed us to maximize the probability of detecting differences

between these groups in their face processing strategies. Once again, analyses focused on three hypotheses.

### **Hypotheses Tested**

First, we hypothesized that attention to the eye region and core features of the face would positively correlate with face recognition skills while attention to the more extraneous outer features of the face would negatively correlate with face recognition skills. These hypotheses were supported with high performers generally devoting more attention to the eye region than low performers. Likewise, high performers devoted a significantly greater amount of attention to the inner features (eyes, eyebrows, nose and mouth) than their low-performing counterparts. The low performers, on the other hand, devoted more attention than the high performers to the outer features of the face (forehead, chin, and neck).

These differences, however, were only detected when measured in raw looking time and proportion of duration of looking time. They were not detected when measured as a proportion of fixations. It is possible that, by converting the scores to a proportion of fixations, informative variability between children was reduced. Regardless, CFMT-C scores did not significantly correlate with overall looking time to the face, suggesting that it is attention to the eyes specifically, rather than looking time overall, that correlates with better face recognition skill.

Furthermore, analyses of attention to individual areas of the face produced a few interesting findings. Correcting for multiple comparisons, both the eyes and cheeks yielded a significant difference between the two groups of recognizers, supporting the

hypothesis that high performers attend more to the eye region and low performers attend more to extraneous features—in this case, the cheeks. These results support the data from Experiments 1 and 2 and the general theory that the eye region is important for successful face recognition. Once again, these data do not support the findings from Yang et al. (2012), who found that attention to the eye region negatively correlated with face recognition skill in a population of Chinese adults.

Second, we hypothesized that high performers would show a greater degree of configural processing compared to low performers. Only recently has the relationship between configural processing and face recognition been demonstrated in adults via the investigation of individual differences (DeGutis et al., 2013; Richler et al., 2011; Wang et al., 2012). The data from Experiment 3 generally converged on the findings from Experiment 2, with high performers showing a greater degree of configural processing than low performers. However, when the variance explained by the Object Task was removed, the relationship between the CFMT-C and the PW-Kids Task was reduced. Therefore, it is possible that more general recognition mechanisms, not specific to faces, is associated with configural processing. However, given the significant relationship between Residual Face Recognition Score and Residual Part-Whole Score of Experiment 2, which used a larger sample, we believe it is likely that this relationship exists.

It is also possible that the Object Task does not serve as an adequate control. One of the difficulties of face recognition research is finding a control stimulus that is similar to faces in terms of the way in which the structure varies within-class, but is an object. Pairs of eye glasses were chosen because they have a standard structure, but

differ between glasses in terms of the minor structural aspects and the individual features. However, eye glasses are worn on the face. This complicates the use of this stimulus as a control. Although every control has its limitations, future work might use another type of object, such as bicycles or houses as a control stimulus.

Third, we hypothesized that measures of configural processing would correlate with attention to the eye region, providing evidence that the eye region, in particular, is used in configural processing. Although this relationship was significant in Experiment 2, we did not find evidence of this relationship in Experiment 3. Again, it may be that the subtle relationship between configural processing and attention to the eye region was more easily detected in Experiment 2, which used larger sample. Future work might evaluate larger samples of high and low performers in order to maximize both sample size and differences between groups. Doing so might further elucidate the relationship between global and local processing.

To further evaluate the role that configural and feature-based processing play in face recognition, we also ran a regression to see how these factors, together, predict face recognition skills. In this case, both predictors were significant when predicting CFMT-C scores suggesting that they may represent two independent processes. However, when using Residual Face Recognition score as the predicted variable, variance explained by the PW-Kids task was no longer significant. These results are in contrast with Experiment 2 and complicate the story. Given these opposite results, it is likely that 1) the control task (Object Task) may be an inadequate control task and 2) that both configural and feature-based processing play a role in face recognition. It is also likely



that there is some overlap between configural and feature-based processing, with attention to the eyes contributing to effective configural processing.

Finally, we assessed social loneliness in each child to see if children with low face recognition skills experienced a greater degree of social loneliness than their high performing, age-matched, counterparts. These comparisons yielded no significant correlations between face recognition skill and questionnaire outcomes and no differences between groups. This is somewhat surprising given the reports in the literature that those with DP experience social difficulties (Diaz, 2008; Yardley et al., 2008). Although, there are several possible explanations for the present findings. First, the individuals described in Diaz (2008) and Yardley et al. (2008) were not chosen for participation as part of a random sample. Rather, they were pre-selected because they experienced face recognition impairment that affected their everyday life and severe enough to be considered DP. It is possible, however, that there are many adults and children with DP who are largely unaffected in a social domain and have not sought out treatment. Likewise, the low performers described in this Experiment likely did not have as extreme of a face recognition impairment as those described in Diaz (2008) and Yardley et al. (2008). Therefore, it is possible that examining the social skills of only children with DP would yield significant findings on this measure. Finally, the social questionnaire was rather brief. It is possible that collecting a more complete profile of social experiences, with semi-structured interview, would allow us to detect subtle differences between groups in social experiences.

## **Evaluation of Measures Used**

In addition to these findings, Experiment 3 provided the opportunity to evaluate each of the measures used. First, as children were pre-selected for inclusion based on their initial CFMT-C score from a previous visit, we had the opportunity to examine the test-retest reliability of this measure. The relationship between first and second CFMT-C score was high [ $r=0.70$ ], replicating our previous findings. This high degree of consistency is impressive considering that differing amounts of time had passed for different cohorts of children. For example, some children were originally tested at 8 years-of-age and again tested just months later. Other children were 10-years-old at the time of initial testing and later tested at 13 years-of-age. Thus, the test-retest reliability of the CFMT-C seems to be very robust. In addition, the CFMT-C and the CFMT-Kids scores were again significantly related to one another, further validating these tasks for future work with children of this age group.

Likewise, as in Experiment 2, the PW-Kids task proved to be effective in demonstrating a whole over part-advantage in face processing for these children. More specifically, this task produced a floor effect for only the low performers on part-trials [ $M = 0.68$ ,  $SD = 0.12$ ]. Regardless, this floor effect was not significant enough to abolish the whole advantage for this group.

Finally, Experiment 3 again provided data on the 3-alternative forced-choice version of the Object Task. With no floor effect for either high or low performers, and a nice distribution of scores, this task will be useful as a comparison with the 3-alternative forced-choice CFMT-Kids Task.

## **Conclusions**

In sum, the findings from Experiment 3 generally replicate the main conclusions of Experiments 1 and 2—namely, that configural processing and attention (or lack thereof) to particular areas of the face are predictive of face recognition scores in children. In particular, Experiment 3 provided clear evidence of differences between high performers and low performers in attention to various regions of the face.

## **CHAPTER 5: Experiment 4**

### **Introduction**

Another way to validate the hypotheses that global processing of faces and attention to the eye region of faces is limited in children with poor face recognition skills is to directly test children who have already been identified as having DP. Previous studies investigating face recognition in adults, have demonstrated that adults with DP often show limited configural processing of faces (Avidan et al., 2011; DeGutis et al., 2007; DeGutis et al., 2011; Farah et al., 1995; Palermo et al., 2011) and possibly insufficient processing of the eye region of the face (Caldara et al., 2005; Ramon & Rossion, 2010; Schmalzl et al., 2008; Stephan & Caine, 2009; Xivry et al., 2008). Based on these findings, and the findings from Experiments 1 through 3, we hypothesized that children with DP would show less attention to the eye region, more attention to the extraneous areas of the face, and less of a configural processing effect compared to their typically developing peers.

## Method

### Participants

Participants included 6 children with suspected developmental prosopagnosia. One additional child was excluded from data analyses because she failed to complete the minimum tasks for inclusion (she only completed the CFMT-C). Parents of the included children contacted the lab with concerns about their child's face recognition skills. Due to limited access to this population, any child who was able to participate, regardless of their age, was included in the sample. Thus, for some of these children, we did not have adequate comparison data from age-matched typically developing children but we included their data nonetheless for illustrative purposes. Nonetheless, direct statistical comparisons with the 8-year-old data are only completed for children 8-years-old and above.

### *Cases*

“B” is an 8-year-old male with uncomplicated medical history. He is of above-average intelligence. Although he has been provided with a diagnosis of DP from a pediatric neuropsychologist, he has not been diagnosed with any other disorders such as Autism. His parents contacted the lab after suspecting a face recognition difficulty and have brought him in numerous times for testing. In the lab, B was very social and enjoyed interacting with researchers. He showed no evidence of difficulty recognizing objects or facial emotion. However, his mother has suggested that he may have difficulty with age recognition. His parents report that he may have an aunt with face recognition impairment, but his parents and younger sibling do not experience face recognition

difficulty. Currently, B is home-schooled in part because of face recognition-related anxiety at school.

“MF” is a 12-year-old female given a formal diagnosis of cortical visual impairment to explain her face recognition difficulties. Her mother reports that she relies on voices and hairstyle to recognize others. In addition to face recognition impairment, MF experiences difficulty with age discrimination and gender discrimination. Furthermore, she has difficulty with navigation and the identification of common sounds and scents.

“RK” is 9-year-old (chronological age) male born with congenital cataracts. Institutionalized in infancy, he had his cataracts removed around the age of 4 before being adopted. Shortly after his adoption, it was determined that RK had scar tissue remaining (from his cataract surgery), which was removed after arriving in the US. Thus, RK was essentially blind until age 4. At the time of adoption, his developmental age was determined to be approximately 2 years younger than his chronological age due to emotional, physical, and cognitive delays. Since his adoption, RK has shown a remarkable improvement in visual capabilities with remaining deficits documented only via strabismus, with associated impairment in depth perception, and visual agnosia. In addition, he experiences the crowding-phenomenon. Academically, he experiences severe dyslexia and speech delay, but is keeping up with his peers. In addition to face recognition impairment, his parents believe that he has difficulty with emotion recognition and gender recognition. Likewise, he has difficulty with object recognition, especially within-class discrimination (e.g. distinguishing one car from another car).

Aside from the above deficits, RK has been tested to have average intelligence. After very thorough screening, it was determined that RK does not have an autism spectrum disorder, despite similar characteristics as a result of prosopagnosia. Albeit very shy, RK is a very social child and enjoys being with others he knows.

“WC” is an 8-year-old male with an uncomplicated medical history. His parents began to notice a face recognition difficulty when he was 7 years old and unable to identify his friends at school. He tends to identify others by their contextual environment (e.g. the car they arrive in). He has no difficulty with object, gender, or age recognition but shows some signs of an emotion recognition difficulty. In addition to face recognition impairment, he experiences difficulty with phonemic awareness. He was evaluated for a possible autism spectrum disorder, but this was ruled out.

“CN” is a highly social 5-year-old female. Her parents first suspected face recognition difficulty when she was unable to identify her playmates at school. She had strabismus that was corrected surgically at 3 years of age. In addition to face recognition difficulties, CN experiences difficulty with gender and age recognition, according to her parents. She has been evaluated for an autism diagnosis but both the school and a clinical psychologist have ruled this out. However, her mother suspects that a diagnosis of ADD would be a good fit for her.

“OP” is a 6-year-old male with an uncomplicated medical history. His parents suspected that he was unable to recognize faces around the age of 4 years when he was unable to recognize his teacher in preschool and failed to recognize his father. OP also has difficulty with emotion recognition but has no difficulty with age, gender, or object

recognition. He has a clinical diagnosis of Asperger's but is considered extremely high functioning.

### **Apparatus, Stimuli, and Procedure**

The apparatus, stimuli, and procedure from Experiment 4 were identical to Experiment 2 with one exception. ML, RK, CN, and OP were all tested on the same day with limited time constraints. Because of this, we omitted the PW-Adult task. Any other exceptions are noted in the result section for each child.

## **Results**

### **Face Recognition, Configural Processing, and Object Recognition**

The face recognition, configural processing, and object recognition scores for each participant are presented in Table 6 alongside the means and standard deviations for each test for 8-year-old typically developing children. However, it should be noted that only B (age 9), MF (age 12), RK (age 9), and WC (age 8) are old enough to compare their scores with the data from 8-year-old children. OP (age 6) and CN (age 5) were included for illustrative purposes; however, we did not have adequate comparison data for these age groups.

	CFMT-C	CFMT-K	PW-K Part	PW-K Whole	PW-K Whole Adv	Object
8 year old TD children	.728 (.092)	.625 (.128)	.650 (.122)	.811 (.106)	.161 (.133)	.672 (.139)
B	.7 (a)	.5	.809	.666	-.142**	(b)
MF	.516**	.458	.238**	.5**	.261	.633
RK	.583*	.479	.428*	.533**	.104	.366**
WC	.516**	.44	.523	.733	.209	.78
CN	.583*	.354**	.333**	.5**	.166	(c)
OP	.533**	.375*	.523	.666	.142	.5

Table 6. Task Performance from each Participant in Experiment 4. Data is presented from typically developing (TD) 8-year-old children from Experiment 2 alongside data from each child with prosopagnosia from Experiment 4. Scores falling at least 1.5 standard deviations below the mean for 8-year-old children are indicated with an asterisk (\*). Scores falling 2 standard deviations below the mean are indicated with a double-asterisk (\*\*). (a) B has completed this test many times as a result of an earlier intervention study. Since that time, his score on this task has dramatically improved so that he is no longer falling 2 sd below the mean for his age group. However, when he was 8-years-old, he was consistently performing 2 sd below the mean on this task. (b) Due to limited time constraints, B did not complete the Object Task. However, has taken various versions of this task in previous visits to the lab and consistently does not show an object recognition deficit. (c) CN, due to inattentiveness at the end of the study, did not complete the Object Task.

In sum, all children except B performed at least 1.5 SD below the mean on the CFMT-C. This is especially surprising for MF and RK who are older than 8-years-old. Given that B has completed this task many times, it is not surprising that his score is higher than 2 SD below the mean. When B took this task as an 8-year-old, however, he consistently performed 2 SD below the mean. On the other hand, only the two younger children performed 1.5 or 2 SD below the mean on the CFMT-K, calling into question the efficacy of this task in the identification of children with prosopagnosia. This is



further discussed in the discussion of this section.

On the PW-Kids task, RK performed 1.5 SD below the mean on part trials. MF and CN performed more than 2 SD below the mean on part trials. Interestingly, MF and CN performed substantially below chance level performance on this task. It is unclear what these children were doing to achieve this below-chance performance. This is particularly surprising for MF who was 12-years-old at the time of testing. She gave no behavioral indication of intentionally answering incorrectly on any other test or on whole-trials. However, there is little explanation for this performance. Likewise, all three children, RK, MF, and CN, performed at least 2 SD below the mean on whole trials. Overall, every child except B demonstrated a whole advantage. However, note that, despite their whole advantage, RK, MF, and CN all performed near chance levels on whole trials, calling their “whole-advantage” into question. Most interesting of these data is B’s performance on the PW-Kids Task. B demonstrated a fairly significant part advantage, rather than whole advantage. Although we would expect those with DP to lack a whole advantage—those who fail to process faces configurally should show no difference between part and whole-trial performance—it is surprising to see a part-advantage as this suggests that the context of the face was actually hindering his recognition ability. This is especially surprising given that he did rather well on the part trials.

Finally, of all of the children, the only child that we suspected might show an object recognition impairment, given their case histories, was RK. Indeed, RK showed an object processing deficit as evidenced by the Object Task, performing 2 SD below the mean. This is not surprising given his history of congenital cataracts and limited early

visual experience.

### Eye Tracking

Data from participants were not excluded due to limited eye tracking data because, if children were not attending to the face, we wanted to note such exceptionalities in this special population. Because the raw looking time data were most informative from Experiments 2 and 3, we analyzed the raw looking times to each area of the face for each child. Looking times are summarized in Table 7.

	Chin	Forehead	Cheeks	Eyes	Eyebrows	Mouth	Neck	Nose	Total Face
8 year old TD children	1.15 (1.58)	1.86 (1.74)	4.41 (3.12)	24.84 (9.09)	7.57 (5.21)	5.17 (3.96)	0.52 (1.03)	11.97 (6.15)	57.57 (8.2)
B	0.72	3.4	6.32	26.9	4.7	2.8	0	15.65	61.5
MF	0.5	1.36	8.57	19.79	3.38	14.82	0.36	25.94	73.12
RK	1.82	0	18.55	18.68	2.17	3.06	0.24	8.98	53.67
WC	0.2	0.84	2.88	11.58	10.67	0.96	0	7.18	34.23
CN	2.89	2.77	5.98	7.9	1.8	5.95	0	8.63	36.23
OP	1.94	1.18	2.84	31.57	1.66	1.1	0	9.9	50.76

Table 7. Raw Looking Times on the CFMT-C for each AOI from each Participant.

Furthermore, for each child, we converted looking times into z-scores in order to examine each AOI side-by-side for a visual comparison (Figures 21-24). Because CN and OP were too young for comparison with 8-year-old data, they were excluded from this analysis. For each graph, *Inner* features included eyes, eyebrows, nose, and mouth and *Outer* features included the neck, forehead, and chin.

*B*

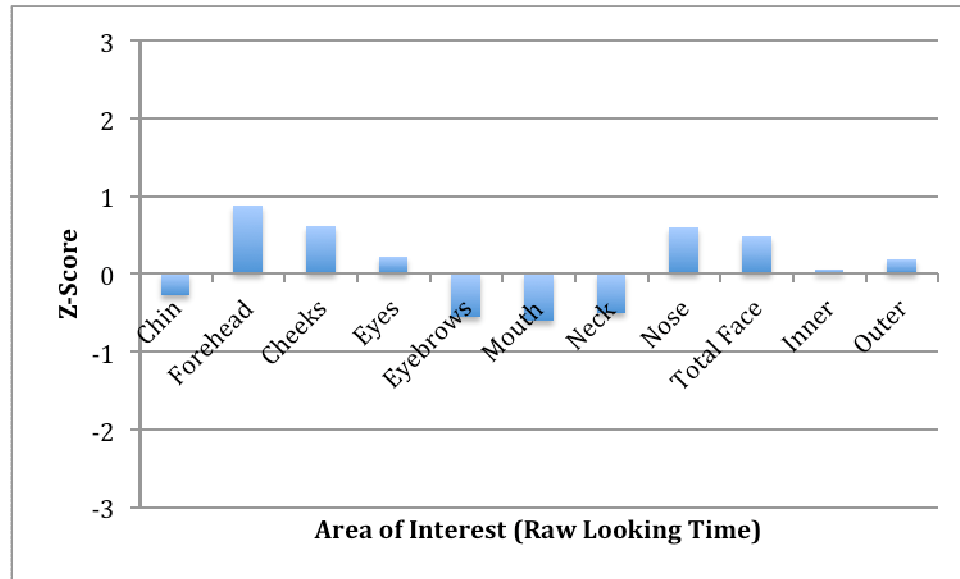


Figure 21. Raw Looking Time to each AOI for B, Presented as Z-scores.

B was the only child for which there was no abnormal tracking indicated by looking times at least 2 SD above or below the mean. This is interesting considering that B was also the only child who performed within the normal range on the CFMT-C. However, as indicated above, when B first came to the lab as a 7-year-old, he produced chance performance on the CFMT-C for several iterations. Thus, it would have been interesting to see how B's eye-tracking behavior on this task has changed with this CFMT-C data. Unfortunately, his early attempts at the CFMT-C did not include eye-tracking.

MF

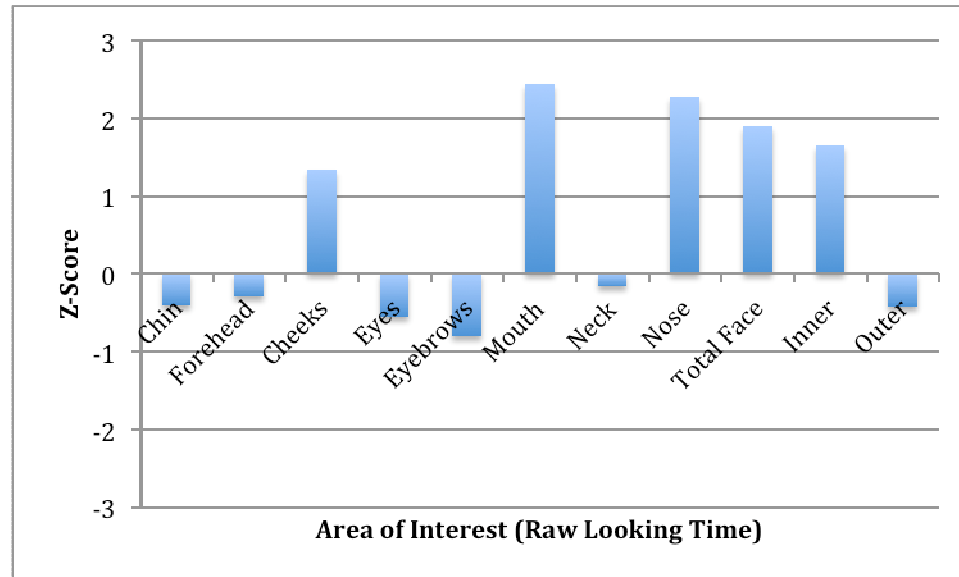


Figure 22. Raw Looking Time to each AOI for MF, Presented as Z-scores

The most striking aspect of MF's looking patterns to faces is her higher than average attention to the mouth and nose. Thus, although she attends to the *Inner* features of the face as would be predicted by the literature, her attention is biased toward the lower features, rather than the eyes and eyebrows.

RK

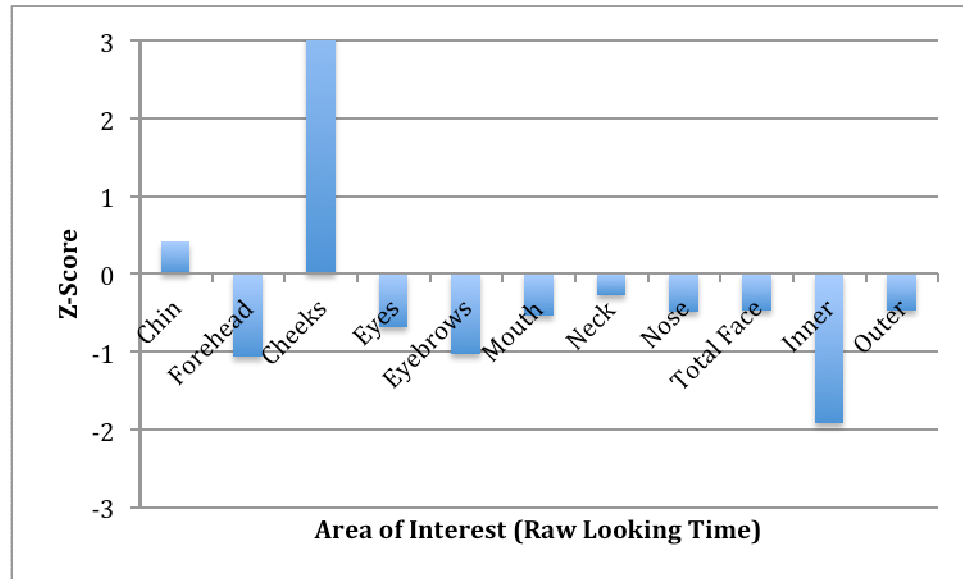


Figure 23. Raw Looking Time to each AOI for RK, Presented as Z-scores

RK's looking patterns toward faces is particularly striking because of his fairly typical pattern of face recognition with the sole exception of attention to the cheeks. Performing more than 4 sd above the mean in attention to the cheeks, this data supports the hypothesis that those with face recognition difficulties may spend an usual amount of time attending to the extraneous areas of the face. However, based on the results from Experiments 1 and 2, mainly lack of significance in the correlation between attention to the cheeks and face recognition score, we did not include the cheeks in the *Outer* areas of the face. Therefore, RK may have a attention pattern that is unique, possibly as a result of his limited early visual experience with cataracts.

WC

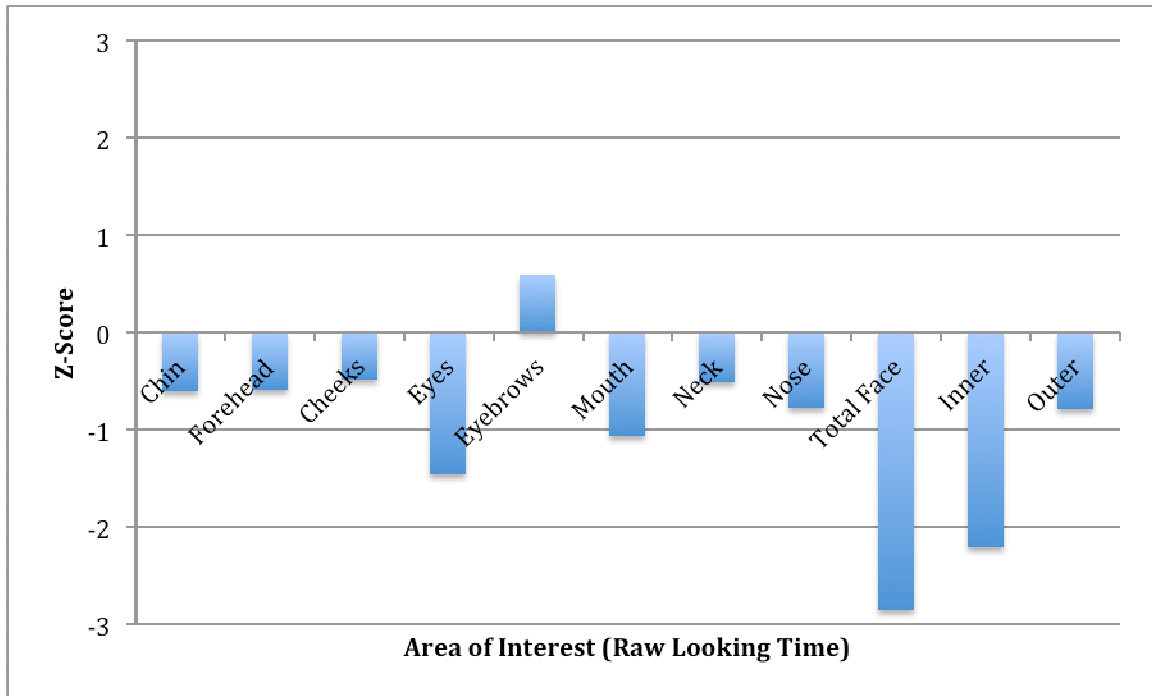


Figure 24. Raw Looking Time to each AOI for WC, Presented as Z-scores

Finally, WC showed a rather typical distribution of looking times to each area of the face on the CFMT-C. The only exception is the amount of time that he attended to the inner features of the face overall. However, this lack of attention to the inner features seemed to be carried by a lack of attention to the face overall. However, it should be noted that WC was very compliant during testing and showed no signs of general inattentiveness (e.g. boredom, failure to cooperate, etc).

### Discussion

The goal of Experiment 4 was to evaluate the hypotheses of this thesis by examining a group of children with DP. Specifically, we hypothesized that if individual differences in configural processing and attention to particular areas of the face can explain face recognition in typically developing children (as in Experiments 1-3), then

children with DP should show abnormalities in these measures when completing the same tasks (CFMT-C with eye tracking and PW-Kids).

All of the children who completed Experiment 4 showed impairments in face recognition as measured by the CFMT-C with the exception of B. This is not surprising given that B has completed this task several times previously in our lab. However, it should be noted that the first several times that B completed this task—ages 7 and 8—he consistently performed more than 2 SD below the mean. Therefore it is either the case that B has improved in his ability to recognize these *particular* faces or, perhaps, that his face recognition skills have improved relative to his peers since he was first tested.

Nonetheless, these children all, at one time or another, performed more than 2 SD below the mean on this task. Furthermore, they presented a rather heterogeneous group, with some, but not all children reporting deficits in age, gender, and emotion recognition. This is consistent with studies of adults with DP that show variability between cases in the degree to which they are affected by other face processing impairments (Chatterjee & Nakayama, 2012; Duchaine & Nakayama, 2006). However, only one child experienced object recognition impairment in addition to face recognition impairment, which was reflected in his Object Task score.

Finally, one child, OP, was additionally diagnosed with an autism spectrum disorder. Given the similarities between autism spectrum disorders and DP, it is difficult to determine if his face recognition impairments are a result of DP comorbid with autism or rather a result of autism itself (Dalrymple et al., 2012). However, given that OP was only 6-years-old at the time of testing, and therefore not comparable with the 8-year-old

data, this is somewhat of a moot point.

The first hypothesis examined in Experiment 4 was that children with DP would show deficits in configural processing as measured by the PW-Kids Task. Of the children old enough to compare with the 8-year-old data, this hypothesis was generally supported with one child showing a part, rather than whole advantage (B) and two children (MF and RK) showing a whole advantage but nearly chance performance on whole trials. The latter data suggests that a floor effect for “Whole-Advantage Scores” likely limited the detection of impaired holistic processing using a subtraction method (whole trial performance minus part trial performance) for these children. Furthermore, this was exacerbated by their unusual below-chance performance on the part-trials. Regardless, three of the four children above 7-years-old demonstrated some form of configural face processing impairment.

The second hypothesis examined in Experiment 4 was that children with DP would exhibit less than typical attention to the eye region, or inner regions, of the face and greater than typical attention to the outer, extraneous, areas of the face, such as the forehead, neck, and chin. Of the six children evaluated, four demonstrated some degree of abnormal attention to face features compared to the 8-year-old comparative data. Two of these children (WC and CN) produced scores more than 2 SD below the mean in attention to the inner features. However, attending to outer features did not compensate for this lack of attention to the inner features. Rather, these children attended to the face significantly less, overall, than typically developing 8-year-old children. RK, on the other hand, attended to the cheeks far more than his typically developing peers. In fact, the



amount of time he spent looking at the cheeks nearly paralleled the amount of time he devoted to the eye region. Furthermore, MF demonstrated a greater amount of attention to mouth and nose than typically developing 8-year-old children. However, interestingly, this bias of attention toward the lower half of the face possibly came at the expense of attention to the eye region. In fact, MF attended to the nose for a greater amount of time than eyes, a pattern very different than is seen in typically developing children.

The remaining two children, B and OP, did not show any deviations from normal in their eye tracking patterns. However, as stated above, OP was only 6-years-old at the time of testing and his eye-tracking data may not be comparable with 8-year-old norms; although, if this is the case, one might expect it to apply to CN as well. B's tracking data, on the other hand, might be explained by his within-2-SD-score on the CMFT-C from which the eye tracking data was obtained. Therefore, his eye tracking patterns may reflect his fairly accurate face recognition abilities on this task.

Interestingly, none of the six children tested showed deficit in attention to the eye region of the face on the CFMT-C. Thus, although the hypothesis that children with DP would devote greater attention to the non-core regions of the face was supported, these data did not support the hypothesis that children with DP would devote less than typical attention to the eye region of the face. This is perplexing. However, it may be the case that those with DP, rather than showing less than normal attention to the eye region, show abnormal attention to at least one outer feature of the face. In this case, children may be very heterogeneous, with each child having a different abnormality in where they choose to direct their attention. To this effect, understanding this information, and what aspects

of facial attention are affected in each child, will be important for identification of cases and treatment.

In addition to these findings, Experiment 4 provided the opportunity to examine the usefulness of each task in evaluating the face and object processing abilities of children with DP. As stated above, the CFMT-C was highly successful at detecting face recognition impairment in these six children. The same was not true, however, for the CFMT-Kids. Only the two youngest children (ages 5 and 6) performed more than 1.5 standard deviations below the mean for 8-year-old children. Given their ages, this is not particularly surprising. However, preliminary CFMT-Kids data, collected by collaborators at Dartmouth College, provides indication that MF and RK both perform at least 1.5 SD below the mean when compared with their own age group. More specifically, MF (age 12) obtained a score of 0.458 on the CFMT-Kids. This places her approximately 4 SD below the mean for typically developing 12-year-old children [ $n = 15$ ,  $M = 0.794$ ,  $SD = 0.086$ ]. Likewise, RK (age 9) obtained a score of 0.479 on the CFMT-Kids. This places him approximately 1.5 standard deviations below the mean for typically developing 9-year-old children [ $n = 15$ ,  $M = 0.70$ ,  $SD = 0.14$ ] (Dalrymple, 2013). Therefore, both MF and RK show impaired scores on both the CFMT-C and CFMT-Kids. However, the finding that both B and WC performed within 1.5 standard deviations for their age-group is somewhat surprising. Both children report significant face recognition impairments in everyday life and performed 2 SD below the mean on the CFMT-C at the time of first testing. Therefore, the CFMT-Kids may not be as sensitive as the CFMT-C in identifying children with DP.

The usefulness of the PW-Kids task with this group of children is a bit more perplexing. First, nearly all of the children exhibited better performance on whole trials than part trials. However, for MF, RK, and CN, their whole-trial performance was near chance, calling into question this whole-advantage. It is not clear why or how these children could have achieved such low performance on part-trials, thus creating a whole-advantage. However, it is not surprising that their whole-advantage was not significantly different than the mean for 8-year-olds given that, in order to have a whole advantage that is 2 SD below the mean, one would actually need to have part-trial advantage. Therefore, it is likely that all of the children except WC and OP had some degree of holistic processing impairment relative to typically developing 8-year-olds.

Finally, the 3-alternative forced-choice Object Task proved to be very useful for examining children with DP. Prior to data collection, RK was the only child that we expected to have an object recognition impairment based on his everyday experiences. This hypothesis was confirmed by performance on the Object Task, with only RK performing 2 SD below the mean. This confirms the usefulness of this task for evaluating children for general object recognition impairments.

In sum, the data collected from six children with DP general supports the hypotheses that configural processing and local attention to particular areas of the face – or in this case, lack of attention to the core regions of the face—are important for face recognition. However, the hypothesis that children with DP would lack attention to the eye region was not supported. It may be with a larger sample, or comparing with an age-matched control sample, that a difference in the attention to the eye region would be

detectable. Further work examining eye-tracking in children should examine this hypothesis with a larger sample of children with DP.

## **CHAPTER 6: General Discussion**

The goal of the present thesis was to examine individual differences in face recognition abilities between children. More specifically, across 4 experiments, we aimed to evaluate what information, provided by the face, is most useful for face recognition.

### **Theories of Face Recognition**

#### **Configural Processing**

There are two main theories in the literature that address this question. First, that the use of configural face information, such as the distance between features or holistic information, is essential for successful face recognition. This theory is supported by experiments examining the inversion effect (Yin, 1969), the composite-face-effect (Young et al., 1987), and the part-whole effect (Tanaka & Farah, 1993). However, only recently has this hypothesis been directly examined by looking at individual differences. Richler et al. (2011), Wang et al. (2012), and DeGutis et al. (2013) all found evidence that configural processing abilities significantly correlated with face recognition abilities in adults. DeGutis et al. (2013) further emphasized the importance of using regression to isolate configural processing rather than the popular subtraction method.

The present thesis aimed to examine this same question in children. Across three studies, children completed the Part-Whole Task (Tanaka & Farah, 1993) as a measure of their face recognition abilities. In general, the hypothesis that there would be a

relationship between configural processing and face recognition skill was supported. In Experiment 2, performance on a measure of face recognition (CFMT-C) significantly correlated with configural processing skills as measured by the Part-Whole Task. This was true when configural processing was measured using regression as suggested by DeGutis et al. (2013), but not when using the subtraction method. The relationship between these variables was also significant when examining the Residual Face Recognition scores unexplained by object recognition performance. Furthermore, similar results were found in Experiment 3 with the exception that, with a smaller sample, the correlation between Residual Face Recognition scores and Residual PW-Kids scores was not significant. Finally, Experiment 4 examined children with DP and found that three of the four children 8-years-of-age or older showed impairments in configural processing as compared to a cohort of typically developing 8-year-old children. Together, these experiments generally support the hypothesis that configural processing is important for successful face recognition.

### **Feature-Based Processing**

The second theory addressed in this thesis is that attention to particular local features, specifically the eyes, is important for successful face recognition. Previous work has demonstrated the importance of the eye region in two different ways. First, several studies have shown that, in face recognition tasks, adults attend to the eye region more than any other feature of the face (e.g. Althoff & Cohen, 1999; Barton et al., 2006). Furthermore, the development of clever methods to isolate individual regions of the face has provided evidence that the eye region may be most informative in face recognition

tasks (e.g. Haig, 1985, 1986). However, the only study to directly examine individual differences in face recognition as related to *particular* regions of the face is Yang et al. (2012). They examined individual differences in attention to several regions of the face during a face recognition task and examined how attention to each area predicted face recognition performance. They found that attention to the eye region of the face negatively correlated with face recognition scores suggesting that attention to this region actually hindered face recognition performance. However, as Blais et al. (2008) pointed out, there are differences between cultures in the degree to which we attend to various regions of the face. Thus, although the findings of Yang et al. (2012) do not generally support the notion that the eyes are important for face recognition, it may be that attention to the eye region is specific to Caucasian Westerners, from which the majority of the previous research has been collected.

Thus, we proceeded with the hypothesis that the eyes may be especially informative for face recognition. Furthermore, based on the findings from Schwarzer et al. (2007), we predicted that those with poorer face recognition performance might devote a greater degree of attention to the non-core features of the face, such as the forehead, chin, and neck, than those with better face recognition skills.

Experiments 1 and 2 provided the opportunity to examine how typically developing children, randomly selected from the general population, attend to faces. Both experiments produced the same order of prioritized attention to the face with 8-year-old children devoting the greatest amount of attention to the eyes, followed by the nose, mouth, eyebrows, cheeks, forehead, chin and neck, in that order.

In addition, each of the four experiments allowed us to examine the role of attention to the eye region in face recognition. Experiments 1 – 3 each, generally, produced a significant correlation between CFMT-C scores and attention to the eye region. Although the significance for each experiment depended on how attention to the eyes was measured (e.g. as raw looking time or fixations), these findings nonetheless provide consistent support for the hypothesis that attention to the eye region is important for successful face recognition. Furthermore, these comparisons remained when participants were separated into quartiles (Experiments 1 and 2) or comparing pre-selected high and low performers on the CFMT-C (Experiment 3). However, when examining attention to the eye region in children with DP, one might expect to see reduced attention to the eye region. However, this was not the case. None of the children evaluated attended to the eye region of the face significantly less than the mean for 8-year-olds. It is not clear why this would be the case. Schmalzl et al. (2008) evaluated attention to the face in a child with DP and found limited attention to the eyes before the completion of a training program. It is possible that the specific measures used were not sensitive enough to detect limited attention to the eye region in these children. For example, limited attention to the eyes may be most evident when viewing dynamic faces rather than static images. Future work should investigate this hypothesis.

We also evaluated the hypothesis that the core features (eyes, eyebrows, mouth, and nose), more generally, were important for successful face recognition. Although this hypothesis was not supported in Experiment 2, the comparisons between high and low performing face recognizers yielded a significant difference in attention to these core

features in Experiment 3. Furthermore, in Experiment 4, attention to the core features of the face fell 2 SD below the mean for 2 children with DP. Overall, these findings suggest that the core features of the face are certainly most important for face recognition, with particular importance of the eye region.

Likewise, we evaluated the hypothesis that attention to the non-core regions of the face (forehead, chin, and neck) would predict low face recognition scores in children. Along these lines, we found marginal significance of a negative correlation between attention to the forehead and CFMT-C score in Experiment 1. In Experiment 2, attention to the outer features did not significantly correlate with face recognition score. However, attention to the forehead, neck, and chin (individually) were all marginally significant when corrected for multiple comparisons. Finally, in Experiment 3, attention to the outer features was significantly correlated with face recognition score with when examined as a correlation and also when examined as a comparison between high and low performers. Supporting these findings, in Experiment 4, the amount of time that RK devoted to the cheeks fell more than 4 standard deviations above the mean for 8-year-old children. However, none of the other three children 8-year-old and older showed significant deviations in the outer region. Together, these findings provide evidence that attention to the outer features of the face may hinder face recognition ability. Given that this effect was seen in Experiment 3, which compared extremes of high and low performers, but not Experiment 2, suggests that this may be true for only the most extreme cases of poor face recognition.



In sum, the overall findings from Experiments 1-4 suggest that attention to the eye region is important for face recognition and that, at least in extreme cases, attention to the extraneous areas of the face may actually hinder face recognition performance.

### **Configural and Feature-Based Processing: Mutually Exclusive?**

It need not be the case that configural and featural processing are two processes that occur separately but simultaneously for face recognition. Rather, it may be that these two processes are inter-related. For example, Leder et al. (2001) found that the inversion effect can be produced for the eye region in isolation of the rest of the face. Furthermore, in cases of AP and DP, configural processing is often impaired for only the upper region of the face (Bukach et al., 2006; DeGutis et al., 2012). We tested this hypothesis by examining how attention to the eye region relates to configural processing as measured by the Part-Whole task. In this case, the findings were mixed. In Experiment 2, configural processing significantly correlated with attention to the eyes as measured in seconds. However, when examined as a regression with configural processing and attention to the eyes predicting face recognition score, only configural processing served as a significant predictor of face recognition. However, in Experiment 3, attention to the eyes and configural processing did not correlate with one another. Furthermore, when evaluated as a regression, both attention to the eyes and configural processing significantly predicted face recognition except when predicting Residual Face Recognition scores, in which case, only attention to the eyes served as a significant predictor.

There are several possible explanations for the discrepancy between Experiments 2 and 3. First, the two experiments used different types of samples and sample sizes. It is possible that the normal distribution of face recognizers is biased toward one strategy (configural processing) whereas the extremes are biased toward the other (feature-based). Second, the data from Experiment 3 may simply have been more sensitive and detected that both attention to the eyes and configural processing were significant predictors. In this case, the lack of prediction between configural processing and Residual Face Recognition score may be explained by the Object Task. In this case, it may be that the Object Task is not an adequate control and, thus, removing variance explained by this task is removing important variance specific to face recognition. Future work might examine a larger cohort of high and low performers with a better object recognition control in order to clarify these relationships.

In general, the combined results of Experiments 2 and 3 suggest that it is likely that both attention to the eye region and configural processing are important for face recognition and there may be some common variance between these processes. Rather, attending to the eye region may be an important aspect of global processing.

### **Contributions**

These studies have made a number of significant contributions. First, Experiments 1-3 provide the first detailed examination of eye tracking patterns in typically developing populations of children. Second, Experiments 2 and 3 examined, for the first time, the relationship between configural processing and face recognition skill in children. Finally, Experiment 4 examined one of the largest cohorts of children with DP to-date, comparing

only to Wilson et al. (2010). Doing so allowed us to highlight the heterogeneity of this population; something that is not possible with single-subject research.

### **Implications**

The findings of these studies have several implications. First, it provides a clearer description of how the human visual system uses facial information for the later recognition of faces. Until now, the information that is used in face recognition has been unclear. These studies indicate that both configural and local facial structures provide key information for face recognition.

Second, a better description of how children recognize faces may provide an avenue for identifying DP in children. In Experiment 4, all of the children tested exhibited a deficit in either configural processing or attention to a particular region of the face. Thus, an examination of configural and local processing in childhood cases may provide the opportunity to identify children with face recognition impairment and furthermore provide a *complete profile* of these cases, understanding which aspects of face recognition are impaired in each case rather than trying to identify children with DP based solely on their face recognition score.

Finally, understanding this information may be essential for the development of successful training programs (see below; Future Work).

### **Future Work**

There are several lines of future work that could stem from this research. First, understanding what information is used in face recognition could inform studies investigating how to identify children with face recognition impairments. By evaluating

different age groups, we could examine how these tracking patterns develop with age and perhaps, subsequently, identify children at risk for Autism, DP, or other disorders associated with face recognition deficits.

Likewise, it is not entirely clear that the tracking patterns of these different groups of children will be the same. For example, children with ASD might show a different pattern than children with DP. Furthermore, there may be differences in tracking patterns between different subtypes of ASD. Gaining a better understanding of these atypical patterns could be useful for evaluating differences between groups that may not yet be salient to us.

Similarly, as was seen in Experiment 4, adults and children with prosopagnosia are a heterogeneous population. In fact, there are likely subtypes of the disorder that can be at least partially explained by deficits in either configural or feature-based processing. Therefore, future work should examine a larger sample of individuals with prosopagnosia to see if there are distinctions between those who show configural processing deficits, those who show local processing deficits, and those who show both. It is entirely possible that certain subtypes of prosopagnosia are more likely to benefit from certain types of training. Future work using a larger sample of individuals with prosopagnosia could investigate this question.

Second, the most obvious extension of this work is to apply the findings to the creation of an intervention aimed at improving the face recognition skills of those with DP. To date, only a handful of training studies aimed at improving face recognition skills have been successful. The first training study with an adult with DP was completed by

DeGutis, Bentin, Robertson, & D'Esposito (2007). They trained a 48-year-old female, MZ, to attend to the configural aspects of faces, mainly the distance between the eyes and eyebrows as well as the distance between the nose and mouth. Post training, MZ improved in her performance on tests of face recognition and began to show a face-selective response to faces both in terms of an N170 response and activation specific to faces using fMRI. In addition, she performed similarly to controls on tests of face recognition and reported improvements in this skill in everyday life. Although the effects of training were not retained for longer than 90 days, this finding is critically important to the field because it demonstrates that, at least in some individuals, it may be possible to train face recognition skills.

However, only two training studies have been attempted in children with DP. The first is seen in Brunsdon et al. (2006). Their study of AL, an 8-year-old male, focused on training him to attend to local, distinctive features of familiar faces. Post training, AL was able to correctly identify all but one of the 17 target-familiar faces (pre-training he was only able to correctly identify 6). However, training did not generalize to photographs of people that he was not trained on suggesting that his training affected his ability to remember the target faces only, but not other familiar faces or new faces.

The only other training program created for a child with DP is described in Schmalzl et al. (2008). Much like the study done with AL, K (age 4) was first given a baseline assessment in which she was presented with photographs of familiar and non-familiar faces. An intervention program was devised for K that would train her to attend to the internal features of a set of familiar face photographs. For each face, K was asked

to identify the face and then discuss 5 defining characteristics listed on the back of the photograph (age, gender, and three other local characteristics). After training, K correctly identified 100% of the photographs from the baseline assessment as either familiar or unfamiliar. However, when presented with the same faces from different viewpoints, K's performance did not improve.

Regardless, the above cited treatment studies provide preliminary evidence that face recognition training may be possible. Early treatment, when plasticity is still evident and long before face recognition abilities have matured, may be effective in preventing some of the social consequences of DP. Creating training programs for children with DP that focus on the recognition of new faces will be an important goal for the future.

Using the methods described in this thesis, interventions may be tailored to suit individual children. For example, if a child spends the majority of time looking at the chin, an intervention for them might focus attention on the eyes and limit attention to the chin. Likewise, a child who lacks a whole-advantage in the Part-Whole Task might benefit from training that highlights the configural aspects of the face, such as the distance between features as in DeGutis et al. (2007).

Finally, one of the drawbacks of this study is that it uses static faces for face recognition. In the literature of face recognition studies, stimuli using dynamic faces have less often been used. However, moving faces likely provide additional information that can be used for face recognition that static faces do not. For example, Lander and Chuang (2005) suggested that faces may display characteristic movement patterns that

aid in recognition. Future work using eye tracking may help to identify the degree to which this is true and further explain how faces are recognized.

Likewise, future work may utilize familiar face stimuli (e.g. photographs of friends and family members) rather than unfamiliar face stimuli as in this thesis. In particular, a number of different groups have found that looking patterns to faces differ when the face is familiar than when it is not (Barton et al., 2006; van Belle et al., 2010) (Althoff & Cohen, 1999). Therefore, a direct comparison of configural and local processing between familiar and unfamiliar faces may be fruitful. On the other hand, this study was primarily concerned with how children come to recognize new faces.

### **Conclusion**

The demonstration of childhood cases of DP, coupled with high prevalence rates of DP in adulthood, establishes a need to address the face recognition deficits of these children early in life, before the effects of the disorder become too severe. To accomplish this task, we need a better understanding of how successful face recognition works. The present experiments provided a description of what aspects of the face are most important for successful face recognition. In general, individual differences between children supported the notion that attention to the configural aspects of the face, as well as the eye region, are important for successful face recognition. These findings will be important for developing case-specific training programs for children with prosopagnosia in the future.

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## Appendix 1

### **Instructions for Defining Areas of Interest on the CFMT-C**

**Forehead:** Top of head down to the top of the eyebrows. Bottom of forehead region extends horizontally across the entire face.

**Eyes:** Six sided shape. Innermost point directly on the midline of the face, at the level of the pupils. Topmost point, directly below the bottom of the eyebrow, directly above the pupil. Outermost edge (2 points) at the edge of the face, top:level of top eyelid, bottom: level of bottom eyelid. Bottom-most edge (2 points), left: about one cm below the eye, directly below the leftmost edge of the eye. right: 1 cm below eye directly below the rightmost edge of the eye.

**Nose:** Five sided shape. Top point: midline of face at the height of the pupils. Vertexes 1 cm below eye, abutting the eye vertex. Bottom surface is horizontal, halfway between the nose and mouth.

**Mouth:** Six sided shape. Top surface: midway between nose and mouth. Side points: just outside of, and slightly below the corners of the mouth. Bottom surface: horizontal surface just below the shadow of the bottom lip.

**Chin:** From side points of lip diagonally to the outside of the face. All of the face below the mouth.

**Cheeks:** All regions of face not included in other AOIs are cheeks.

**Neck:** Area of neck, bordered by edge of chin.

## Appendix 2

### *Loneliness and Social Dissatisfaction Questionnaire* (Asher, Hymel, & Renshaw, 1984)

**Scoring:** Both adult and child versions were scored the following way. Each question had the following options: Always true (5), true most of the time (4), sometimes true (3), hardly ever true (2), not true at all (1). The following items were reverse scored: 3, 6, 9, 12, 14, 17, 18, 20, 21, 24. The following items were filler questions and were not scored: 2, 5, 7, 11, 13, 15, 19, 23.

#### Adult Questionnaire (Adapted)

1. It's easy for my child to make new friends at school.
2. My child likes to read.
3. I often feel like my child has no one to talk to.
4. My child is good at working with other children.
5. My child likes to watch TV.
6. It's hard for my child to make new friends.
7. My child likes school.
8. My child has lots of friends.
9. I think my child feels alone.
10. My child can find a friend when he/she needs one.
11. My child enjoys playing sports.
12. My child struggles to get other children to like him/her.
13. My child likes science.
14. My child often has no one to play with.
15. My child likes music.
16. My child gets along with other children.
17. My child often feels left out.
18. I feel that my child feels they have no one to go to when they need help.
19. My child likes to paint and draw.
20. My child doesn't get along well with other children.
21. My child is lonely.
22. My child is well-liked by other kids in his/her class.
23. My child likes playing board games.
24. My child doesn't have any friends.

#### Child Questionnaire

1. It's easy for me to make new friends at school.
2. I like to read.
3. I have nobody to talk to.
4. I'm good at working with other children.

5. I watch TV a lot.
6. It's hard for me to make new friends.
7. I like school.
8. I have lots of friends.
9. I feel alone.
10. I can find a friend when I need help.
11. I play sports a lot.
12. It's hard to get other kids to like me.
13. I like science.
14. I don't have anyone to play with.
15. I like music.
16. I get along with other kids.
17. I feel left out of things.
18. There's nobody I can go to when I need help.
19. I like to paint and draw.
20. I don't get along with other children.
21. I'm lonely.
22. I'm well-liked by the kids in my class.
23. I like playing board games a lot.
24. I don't have any friends.