Examining Face Template Representation and Adaptation

# EXAMINING FACE TEMPLATE REPRESENTATION AND ADAPTATION ACROSS SOCIAL AND EMOTIONAL CATEGORIES IN ADULTS AND CHILDREN

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## Lay Abstract

Humans are quick at noticing social aspects of faces and rely on mental representations of how faces appear. Our mental representation of a face is based on faces we encounter and can be influenced within the laboratory. Across four studies we examined and manipulated adults and children's mental face representations. Chapter 2 revealed that children's reference to facial expression mental representations develops from 6-15 years of age. Chapter 3 discovered that if religious membership is made significant to adults, they have separate representations for Christian and Muslim faces, but 8-year-olds do not. Chapter 4 found that our mental representations may incorporate the diversity of social groups as a separate social category of faces. Chapter 5 revealed that manipulating multiple face representations persists for several days. This body of work demonstrates the complexity of our face representations, and how this beneficial skill for face perception adapts based on our experience.

## Abstract

The ability for humans to quickly and accurately extract information from faces is a highly relevant social-cognitive skill. Much of the expertise adults have with faces has been attributed to norm-based coding (Valentine, 1991), referring to cognitive representations of face templates. Our face templates are generated based on our experience with faces and are consistently updating. Several separate face templates for different social categories have been observed. These mental representations can be manipulated within the lab to examine more about adults and children's organization and reliance on face templates. This dissertation explored how children's reliance on norm-based coding develops, new circumstances in which separate face representations are formed, and how long in-lab manipulations of multiple face representations persist. Chapter 2 revealed novel information about children's reliance on norm-based coding for facial expression perception, demonstrating a long developmental trajectory to adult-like perception from 6-15 years of age. Chapter 3 discovered a new social categorical mental representation, religion. This chapter demonstrated that adults are capable of having separate cognitive representations for Christian and Muslim faces if the religion is made relevant to them; however, this was not observed in 8-year-olds. Chapter 4 found the first ability to manipulate mental representations of faces that are diverse, and that diversity itself can be a cue to face category membership. Chapter 5 examined how long manipulating multiple face representations persists through an opposing aftereffects paradigm, revealing a slower decay from other forms of manipulations. These studies demonstrated the complex nature of our cognitive face representations. This dissertation contributes new discoveries on norm-based coding, uncovering children's developing reliance on norm-based coding, new circumstances in which separate face templates evolve in adults and children, and how long manipulating our face space may persist under opposing aftereffects paradigms. Recognizing differences in faces is an essential human skill; examining face template representations allows for discovering how our mind develops this face perception expertise.

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### Chapter 4

**List of Abbreviations and Symbols**

α, Cronbach's alpha

*β*, standardized beta coefficients

Δ, delta

$\eta_p^2$, partial eta squared

2 AFC, two alternative force choice

ANN, artificial neural networks

ANOVA, analysis of variance

ASD, Autism spectrum disorder

*b*, unstandardized beta coefficients

C-M+, Christian contracted/Muslim expanded, adaptation condition

C+M-, Christian expanded/ Muslim contracted, adaptation condition

CI, confidence interval

cm, centimeters

*cocor*, comparing correlations, R package

*d*, Cohen's *d*

ERP, event-related potentials

*F*, F ratio

*f,* Cohen's *f*

FFA, fusiform face area

FSIQ, full scale intelligence quotient on the WISC

ID, identification

IQ, intelligence quotient

IQR, interquartile range

*k*, number of groups

*M*, mean

Min., minutes

*N*, number of participants

OFA, occipital face-selective area

*p*, p value, probability

PR, perceptual reasoning, subsection of the WISC

PS, processing speed, subsection of the WISC

*r*, correlation coefficient

$R^2$, coefficient of determination

s, seconds

*SD*, standard deviation

STS, superior temporal sulcus

SVM, support vector machines, machine learning model

*t,* t test statistic

U.S., United States

VC, verbal comprehension, subsection of the WISC

WISC, Wechsler intelligence scale for children

WM, working memory, subsection of the WISC

$X^2$, Chi-squared statistic

**Declaration of Academic Achievement**

Chapter 2: Dr. Mel Rutherford and I designed the experiments. Experiment 1 utilized the same program and stimuli as Walsh, Vida, and Rutherford (2014). Experiment 2 was designed by me and Dr. Mel Rutherford, I created all stimuli and programmed the experiment. Data collection was completed by me with the assistance of Haichao Zhang, Alyssa Janes, and Eiman Malik. I conducted the data analyses and generated all figures for both experiments. I prepared the manuscript for publication, Dr. Mel Rutherford edited the manuscript, and I revised it.

Chapter 3: Dr. Mel Rutherford and I designed the 3 experiments. I programmed experiment 1, collected the data, and analyzed it. The stimuli were photographed by Alyssa Mueller. Programming for experiments 2 and 3 was by Robert Lava under my supervision and instruction. The audio descriptions were created by me and Alyssa Mueller. I drew the adaptation storybook and created its narrative for experiment 3. Data collection for experiments 2 and 3 was conducted by me with the assistance of Alyssa Mueller and Eiman Malik. I conducted all data analysis and created all figures for experiments 2 and 3. I prepared the manuscript for publication which was edited by Dr. Mel Rutherford, and I revised it.

Chapter 3: Dr. Mel Rutherford and I designed the experiment. The stimuli were edited by Reihaneh Jamalifar under my supervision. I programmed the experiment. The data was collected by me and Jocelyn Van Dyke. I conducted all data analysis and created all figures. I prepared the manuscript for publication which was edited by Dr. Mel Rutherford, and I revised it.

Chapter 4. Dr. Mel Rutherford and I designed the experiment. I created the program and materials. The data was collected by me and Maha Siddiqui. I conducted all data analysis and created all figures. I prepared the manuscript for publication which was edited by Dr. Mel Rutherford, and I revised it.

# Chapter 1: Introduction

Faces represent some of the most important social stimuli we see day to day. Though there is much variability in faces, we are capable of extracting a plethora of information about them, even if we have not seen or interacted with them before. When approached with a face, we are quickly capable of interpreting social information from it such as their race, gender, how old they are, what emotion they are feeling, and have we met them before? This is a highly relevant social-cognitive skill and is critical for our ability to interact with others. The ability to extract social information from faces rapidly and accurately is essential as a highly social species and has been beneficial to our survival. Being able to infer social-categorical and social-emotional information from others allows for quick interpretation as to how to respond in a given situation. Due to this rapid ability to perceive social information from faces, humans are thought to be experts in face perception.

## Faces are special: Specialized processing for face perception

There is much evidence supporting that humans treat and process faces as special visual information in comparison to other types of visual objects (Farah et al., 1995, 1998; Gauthier et al., 1999). Evidence for this distinction has been illustrated through experiments revealing that faces are processed holistically, differently from objects, that are processed based on their individual parts (Biederman, 1987). Holistic face processing is based on the premise of Gestalt theory, in which the whole is considered to be greater than the sum of its parts

(Köhler, 1924; Wagemans et al., 2012). As faces are made up of the same features across humans (e.g., eyes, nose, mouth), identifying subtle differences between these features is useful in recognizing a presented face (Diamond & Carey, 1986; Le Grand et al., 2004; Leder & Bruce, 2000; Maurer et al., 2002). Therefore, it is thought that faces are perceived as a whole, rather than as a collection of their features separately.

Several studies have demonstrated that we process faces holistically. One of the most famous examples is the inversion effect, in which adults process faces more successfully when they are upright compared to inverted (Yin, 1969). This is due to disrupting holistic processing when the face is inverted. The inversion effect is much smaller for non-face objects, suggesting that the holistic processing of faces is unique in comparison to other visual stimuli (Valentine, 1988). These effects have been also observed in children, (Goldstein, 1965; Hochberg & Galper, 1967) and even for humans bodies that have heads (Reed et al., 2003; Yovel, 2009; Yovel et al., 2010)

Another example of processing faces holistically is observed through the "part-whole" effect (Tanaka & Farah, 1993). Through this paradigm, adults can discriminate and recognize "parts" (e.g., nose, eyes) of a face more accurately when they are presented in the context of a whole face compared to presented alone in isolation. The difference in performance between viewing the "parts" alone versus on a whole face is evidence for processing faces holistically rather than by their individual features. The part-whole effect has also been observed in children at the age of 6 (Tanaka et al., 1998).

Evidence of difficulty disrupting holistic processing can be observed via the composite face effect. During this task, adults view faces comprised of two identities, where one half of a face is from one individual and the other half a different individual. Adults are slower to recognize which half of a face belongs to a questioned identity when the halves of the face are aligned compared to misaligned (Goffaux & Rossion, 2006; Le Grand et al., 2004; Michel et al., 2006). When two different faces are misaligned, it is more noticeable to the viewer which half belongs to each identity. However, when the two different identities are aligned, it is difficult to disrupt holistic processing, making the face look like one new identity (Young et al., 1987). Therefore, even while participants are aware that the two face halves belong to separate identities, it is difficult to disrupt the specialized holistic processing humans have for faces.

Other evidence supports that we have specialized mechanisms for perceiving faces. Face perception utilizes an assorted set of skills across several specialized areas of the brain. One of the most well-known areas in the brain that responds to faces is the fusiform face area (FFA) (Haxby et al., 2000; Hoffman et al., 2000; Kanwisher et al., 1997). This area of the brain is highly activated when viewing faces, and damage to the FFA can lead to inability in recognizing faces (Damasio et al., 1982). Perceiving different parts of the face, such as the eyes, nose, and mouth regions is specialized by the occipital face-selective area (OFA)

(Fairhall & Ishai, 2007; Nichols et al., 2010; Pitcher et al., 2011). In contrast, perception of the changeable areas of the face is found to activate the superior temporal sulcus (STS) (Haxby et al., 2000), which also responds to emotional facial expressions and eye gaze (Allison et al., 2000; Hoffman et al., 2000). Specialized processing for faces has further been observed through event-related potentials (ERP). One of the most commonly investigated ERP components for face perception is the N170 (Bentin et al., 1996; Bentin & Carmel, 2002; Eimer, 2011). Activation in the N170 is defined by a negative peak that occurs approximately 170 milliseconds from the onset of a presented stimulus. This response is reported as larger or more negative after viewing faces compared to other objects (Bentin et al., 1996; Itier & Taylor, 2004b; Rossion et al., 2000). Due to the several specialized brain regions that are activated when viewing faces, faces can be considered a unique type of visual stimuli. As faces are highly relevant information they are considered “special” in comparison to other visual information (McKone & Robbins, 2011).

**Face space: Norm-based coding of faces**

The ability to recognize subtle differences between faces requires visual sensitivity to very similar patterns of information. A major part of this expertise we have with faces has been attributed to the use of norm-based coding. Norm-based coding, as proposed by Valentine (1991), suggests that the visual system solves the problem of similarity by comparing faces to a norm-based template or prototype. Under this view, faces are encoded within a multidimensional “face space" that centers around this norm. Individual faces differ on a variety of dimensions, (e.g., space between the eyes and nose, shape and size of eyes) and each of these dimensions are unique multidimensional vectors from the norm. These differences in dimensions from the norm are critical in identifying information about a new face. Under this framework, the closer a new face is to the centered norm, the more attractive or typical it appears, whereas the farther the face is from the norm the more distinctive or less attractive it appears (Rhodes & Tremewan, 1996; Valentine et al., 2004).

The centered face norm is formed based on the faces we experience throughout our lives. As such, the norm is dynamic, updated based on our experience, and is a reflection of our "face diet" (Rhodes et al., 2003; Webster, 2011, Webster & Maclin, 1999). Evidence for the dynamic malleability of face norms can be observed through visual aftereffects. Face aftereffects can reveal much about the neural coding of faces and how they are represented cognitively. Visual aftereffects that occur after continuously viewing a distorted stimulus are followed by a biased perception of that stimulus towards its visual opposite (Clifford & Rhodes, 2005; Webster, 2011). An example of a face aftereffect is when participants continuously view and adapt to distorted faces (e.g. features of the face are compressed) and afterward undistorted faces appear distorted in the opposite direction from what was adapted to (e.g. features of the face appear expanded) (MacLin & Webster, 2001; Rhodes et al., 2003; Watson & Clifford, 2003; Webster & Maclin, 1999). This is due to a temporary shift in the norm-based template after adaptation to distorted faces. Additionally, during adaptation, our norm begins to encompass the distorted faces causing other similarly distorted faces to be perceived as more attractive than they were before adaptation (Rhodes et al., 2003, Webster, 2011; Webster & Maclin, 1999). Aftereffects exemplify the malleable existence of face norms and the ability to alter the norm within a brief laboratory setting.

Face aftereffects have since been consistently replicated with other forms of face information, for example, face identity. After participants are adapted to a computer distorted opposite of one identity (e.g., “anti-Dan”), an ambiguous face appears to have the original identity’s appearance (e.g. “Dan”) (Jiang et al., 2006; Leopold et al., 2001; Rhodes & Jeffery, 2006; Rhodes & Leopold, 2011). Face aftereffects have also been observed for gender (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Schweinberger et al., 2010; Webster et al., 2004), race (Bestelmeyer et al., 2010; Jaquet et al., 2008; Little et al., 2008; Webster et al., 2004), age (Little et al., 2008; Schweinberger et al., 2010), species (Little et al., 2008), attractiveness (Anzures et al., 2009), viewpoint (Chen et al., 2010), eye gaze (Jenkins et al., 2006; Kloth et al., 2017; Kloth & Rhodes, 2016; Kloth & Schweinberger, 2008), and emotion (Adams et al., 2010; Fox & Barton, 2007; Rutherford et al., 2008; Webster et al., 2004). Replicating aftereffects for several types of face characteristics highlights and strengthens the evidence for norm-based coding of faces.

How long aftereffects persist has also been explored. Aftereffects have been shown to begin decaying quite rapidly, within seconds after adaptation (Leopold et al., 2005; Rhodes et al., 2007). The persistence of aftereffects increases as a function of the length of adaptation duration, with decay dependent on the length of adaptation time (Leopold et al., 2005; Rhodes et al., 2007). This rapid decay for face aftereffects follows a similar pattern of results as other forms of visual adaptation such as tilt (Harris & Calvert, 1989; Magnussen & Johnsen, 1986; Wolfe, 1984), motion (Hershenson, 1989), and shape (Krauskopf, 1954). However, some forms of aftereffects have been found to persist much longer. Colour aftereffects can persist weeks after adaptation (Neitz, Carroll, Yamauchi, Neitz, & Williams, 2002), gaze aftereffects are measurable several minutes after adaptation (Kloth, & Schweinberger, 2008), and up to 24 hours after adaptation (Kloth & Rhodes, 2016). Therefore, adaptation decay is dependent on the stimulus adapted to.

Though norm-based coding is a common theory as to how "face space" is represented, it is often contrasted with an exemplar-based model of "face space". An exemplar-based model for face space proposes that faces are encoded by their location in face space relative to several exemplars of previously encoded faces (Lewis, 2004; Valentine, 1991). Both models posit the existence of a face norm, though through the exemplar model the norm holds no significance. Differentiating between a norm-based and an exemplar-based model has been explored within the field. A norm-based model has been described as using opponent two-pool coding, in which oppositely tuned pools of neurons are responding maximally to the extreme values of each dimension (e.g., the distance between the eyes and nose, are the eyes higher or lower). Through this view, the norm would be perceived when the two pools produce an equal output strength (e.g., eyes in the middle). However, an exemplar-based model has been described as using multichannel coding; values along a dimension are coded by multiple pools of neurons, resulting in a bell-shaped tuning curve for each value. Through this view, values with similar dimensions activate the same set of neurons, whereas differing values activate non-overlapping sets of neurons. An average face is perceived when the pools of neurons that respond to the average values are more strongly activated than those above or below the average (Jeffery et al., 2010; Rhodes & Leopold, 2011). Therefore, the norm-based model is more strongly activated when faces deviate from the norm, whereas the exemplar-based model is more strongly activated when faces are more similar to the norm.

Distinguishing between a norm-based and exemplar-based model has been examined empirically. A norm-based account would predict that perceiving faces that are farther away from the norm should result in a stronger aftereffect, as it results in shifting the norm. Conversely, viewing faces similar to the norm should result in little adaptation as it does not change the norm as much as more distinct faces (Jeffery et al., 2010; Rhodes & Jeffery, 2006). This is because through a two-pooled view, a face close to the norm would be equally activating the opponent pools of neurons and the farther a face is from the norm the more change in response to those two pools there would be. Therefore, more extreme adaptors will produce larger aftereffects than less extreme adaptors. However, an exemplar-based model would predict the opposite: adaptation to faces that are closer to the norm would produce larger aftereffects than faces that are farther from the norm. This is because adaptation is dependent on the amount of overlap there is between the pools of neurons coding for average values. Therefore, an extremely distorted face would produce smaller aftereffects because they would activate very few neural pools as they would share minimal overlap with neurons that activate for average faces.

There has been supporting evidence for a norm-based model of "face space" via neuroimaging research and manipulating adaptation distortion strength. Activation observed in the FFA decreases with multiple presentations of faces that do not vary widely (e.g. multiple presentations of faces that have extremely wide chins), and activation increases when presented faces were farther away from the norm (Loffler et al., 2005). This is consistent with a norm-based view which relies on recognizing deviations from the center norm (Valentine, 1991) and predicts stronger adaptations to more distorted faces (Jeffery et al., 2010). In examining face-responsive neurons in macaque monkeys responses in the anterior inferior-temporal cortex increased when presented with deviations that are farther away from the norm (Leopold et al., 2006). Additionally, in exploring both identity and figural adaptation aftereffects, the more extremely distorted the adaptors are the more change in preference after adaptation there is (Rhodes et al., 2005; Robbins et al., 2007). This is consistent with a norm-based view as the farther the adaptation stimuli are from the norm the more the norm would be expected to shift in that distorted direction. Therefore, there has been much support for the norm-based view of face space as examined via aftereffects.

**The development of face processing and norm-based coding in children**

Children, like adults, show early evidence of perceiving faces as a special type of visual information. Newborn infants show a preference for faces over other stimuli; they are capable of detecting and visually orienting to face-like stimuli over other non-face-like stimuli patterns (Goren et al., 1975; Johnson et al., 1991; Valenza et al., 1996). Within days after birth infants show a preference for their mother's face compared to a stranger's face (Bushneil et al., 1989; Field et al., 1982; Field et al., 1984; Pascalis et al., 1995). Infants have even been found to discriminate and imitate some basic emotions within hours after birth (Meltzoff & Moore, 1983a, 1983b).

Like adults, children show evidence of the face inversion effect (Brace et al., 2001; Itier & Taylor, 2004a; Mondloch et al., 2002; Schwarzer, 2000). Several studies provide evidence that children are capable of holistically processing faces (Carey & Diamond, 1994; de Heering et al., 2007; Mondloch et al., 2007; Pellicano et al., 2006; Pellicano & Rhodes, 2003). Children are found to be more accurate at recognizing upright compared to inverted faces (Cassia et al., 2009; Mondloch et al., 2002). Children show evidence of perceiving their own-race faces more accurately than other-races faces after 9 months (Kelly et al., 2007;

Sangrigoli & Schonen, 2004) and are sensitive to a variety of facial identity cues (Freire & Lee, 2001; McKone & Boyer, 2006; Mondloch et al., 2002). Additionally, the ability to perceive several basic emotions has also been found to emerge early into childhood (De Sonneville et al., 2002; Durand et al., 2007; Gao & Maurer, 2009; Herba et al., 2006).

Though children show some specialized face processing skills early on, their performance compared to adults has been found to improve throughout childhood (Carey et al., 1980; Carey, 1992; Gao & Maurer, 2009; Mondloch et al., 2002, 2003). Children typically make more errors than adults on various face perception tasks (Bruce et al., 2000; Freire & Lee, 2001; Mondloch et al., 2002; 2003). Children are more sensitive to small differences in the individual spacing and features of faces (Freire & Lee, 2001; Mondloch et al., 2002, 2006). Children are more easily misled by paraphernalia (e.g., glasses, hats) when perceiving faces (Baenninger, 1994; Carey & Diamond, 1977; Freire & Lee, 2001). Children's immaturity in face processing compared to adults has also been supported by neuroimaging research. Activation in the FFA that is commonly elicited when adults view faces has not been observed in children until around 12-16 years of age (Aylward et al., 2005; Gathers et al., 2004; Passarotti et al., 2003; Scherf et al., 2007). This pattern of results has also been replicated through ERP studies (Itier & Taylor, 2004b; Taylor et al., 2001).

Given the immaturity children show in face processing, a question of interest is why this is. Some have suggested that over time there are improvements in children's more general cognitive and perceptual abilities that affect face perception (Crookes & McKone, 2009; Jeffery et al., 2010; Mondloch et al., 2006; Pellicano et al., 2006). Concerning norm-based coding, children may still be developing and refining their "face space" as they gain experience with faces. Several studies have examined whether children show evidence for norm-based coding through aftereffects paradigms. Identity aftereffects have been observed in children as young as 4 years of age (Jeffery et al., 2013) and in 7-8-year-olds (Jeffery et al., 2011; Nishimura et al., 2008). Eight-year-old children have shown evidence for attractiveness aftereffects (Anzures et al., 2009), which has also been observed in children as young as 5 years of age (Short et al., 2011). These results exemplify some evidence of norm-based coding abilities in childhood.

Though children are capable of adapting to faces, it has been found that they may need larger distortions than adults to evoke an effect. Anzures et. al. (2009) found that only when the distortion strength was increased from the 60% used in adults to 90% was it possible to observe evidence of adaptation in 8-year-old children. Larger distortions have also been required for adaptation in 5-year-old children (Short et al., 2011). Additionally, children have been found to rely on fewer dimensions when coding faces in comparison to adults, possibly affecting differences in their adaptation ability (Nishimura et al., 2009). However, when examining 4 to 6-year-olds, Jeffery et al., (2010) found comparable simple aftereffects as adults. These results suggest that differences in face-processing abilities in children may not be due to children's norm-based templates differing from adults. However, differences in adaptation may be due to children's reliance and reference to this norm differing from adults. It is possible that the reliance on face norms is a developing skill and could account for some of the differences observed between adult's and children's face perception abilities.

**Opposing aftereffects: Evidence for examining several face norms**

While Valentine's (1991) model of "face space" suggests that we have one face norm, more recent research has investigated the presence of several different face norms. The focus has been put on examining norms that differ based on physical categories of faces (e.g., race, gender, emotion). Having several norm-based templates for different categories of faces would aid in the recognition of different types of faces encountered (Armann et al., 2011). Evidence for this has been explored through opposing-aftereffects paradigms. While simple aftereffects consist of adapting to several faces that are distorted in the same manner (e.g., compressed faces), opposing aftereffects consist of adapting to two separate categories of faces, distorted in opposite directions (e.g. compressed male faces and expanded female faces) (Bestelmeyer et al., 2008; Little et al., 2005). Opposing aftereffects are evident if, after adaptation, attractiveness or normality judgements shift in the direction of adaptation for both of the categories adapted to (e.g., prefer compressed male faces and expanded female faces after adaptation).

Opposing aftereffects are considered evidence for separate face templates. Adaptation to both categories in opposite directions would only be possible if there are two separate face templates that are being manipulated simultaneously, in opposite directions (Jaquet et al., 2008). Essentially, the template for one category is being shifted in one direction, while not disrupting adaptation to the other category template, which is also being shifted in the opposite direction. This is only possible if the two categories have uniquely separate templates. If the templates were not unique, adaptation in only one direction may be observed or no changes in preference at all. Opposing aftereffects have been found for race (Bestelmeyer et al., 2010; Jaquet et al., 2008; Little et al., 2008), sex (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Little et al., 2008; Schweinberger et al., 2010; Watson & Clifford, 2006), age (Little et al., 2008; Schweinberger et al., 2010), species (Little et al., 2008), and expression in adults (Bestelmeyer et al., 2010; Cook et al., 2011; Rhodes et al., 2017; Skinner & Benton, 2010), suggesting several social categorical face norms represented cognitively.

Children's categorical face norms have also been explored through opposing aftereffects. Short et al. (2011) explored whether 8- and 5-year-old children have race-specific norms for Caucasian and Asian faces. To adapt children to an opposing aftereffects paradigm, rather than having children passively view the distorted faces, they modified a storybook adaptation paradigm (Anzures et al., 2009). Through this paradigm, race-contingent opposing aftereffects were observed in 8-year-old children demonstrating separate face norms for Caucasian and Asian faces (Short et al., 2011). However, when examining Caucasian 5-year-olds with the same paradigm race-specific norms were only observed for their own race. When explored further, Short et al., (2014) did not observe race-contingent opposing aftereffects in Chinese 5-year old's, nor Caucasian 5-year-olds with ample experience with Chinese faces. Additionally, Short et al. (2014) examined whether 5-year-old children have separate face templates for age and sex. Though opposing aftereffects for age and sex have been observed in adults (Little et al., 2005; Little et al., 2008; Schweinberger et al., 2010), they had not yet emerged in 5-year-old children (Short et al., 2014). Together these results suggest that much refinement in children's face space is occurring from 5 to 8 years of age. Short et. al (2011) propose two theories: 1) that 5-year-old children may possess separate face templates for race, but their other-races templates may be weaker than the own-race template, or 2) that the other-race template has not yet been refined. While several opposing aftereffects have not been observed in 5-year-old children, race-specific face-norms were observed in 8-year-olds (Short et al., 2011). Evidence of other categorical face templates in 8-year-olds has yet to be further explored.

Though opposing aftereffects can be used to observe the presence of several face templates, there are some necessary stimuli requirements. These requirements have been explored by manipulating how physically distinct (Bestelmeyer et al., 2008; Jaquet et al., 2007) and socially relevant (Short & Mondloch, 2010) face categories are during adaptation. Bestelmeyer et al., (2008) examined whether opposing aftereffects were evoked differently for sex by manipulating how physically distinct the faces were. Participants were adapted to either male and females faces or female and hyper-female faces. The physical differences between the female and hyper-female faces were identical in physical distance from the male and female groups. Even with the physical distance controlled for, opposing aftereffects were only observed for the male and female faces and not the female and hyper-female faces, suggesting social differences are necessary. A similar pattern of results was observed by Jaquet et al., (2007) who adapted participants to either Caucasian and Asian faces or SuperAsian and Asian faces; larger aftereffects were found for the Caucasian and Asian separate race categories than the physically similarly distanced same-race categories. These studies highlight how separate face templates are only evident if the templates are socially meaningful in the real world. It is not enough for the faces to be physically different from each other during adaptation, they must be two socially meaningful face categories to evoke opposing aftereffects.

Additionally, Short and Mondloch (2010) explored whether opposing aftereffects can be evoked based only on social category meaning and not physical differences between faces. Social categories were artificially created in the lab by having participants either become part of a crimson or cyan group based on fictitious feedback on a personality inventory. Participants also wore a wristband that was associated with their group's colour. Then, during adaptation, faces of only Caucasian females were presented (controlling for physical distinctiveness) but on either a crimson or cyan background (provoking an in-group/out-group social category). Participants were told that the background colour indicated whether that face was part of their in-group or out-group. Faces from their in-group were more easily recognized than those from their out-group, however, no opposing aftereffects were observed. Therefore, the social category alone was not sufficient enough to facilitate opposing aftereffects, and some physical difference was necessary during adaptation. From the above series of experiments, it has been recognized that to evoke opposing aftereffects two criteria must be met 1) the faces must come from socially relevant categories, and 2) the categories must be physically distinct from each other.

Opposing aftereffects are an incredibly useful tool to explore the representation of face templates in "face space" however, it would not be economical for non-relevant face norms to emerge (Rhodes & Leopold, 2011). Conceivably, non-meaningful face templates should not be represented cognitively and therefore could not be evoked through opposing aftereffect paradigms. If a face category does not exist in the real world, it would not be a useful template to form in "face space". With this known, there are still several other face categories that have yet to be explored via opposing aftereffects paradigms and much unknown about children's reliance on face norms. How does children's norm-based coding reliance develop, and what other categorical templates do 8-year-olds hold? To what extent can social relevance be manipulated to alter our "face space"? What other social categorical templates do adults have? How does our "face space" handle adaptation to face categories that physically vary within groups? Finally, how long does this adaptation persist when manipulating multiple face templates? These gaps in understanding adults' and children's face space have yet to be explored.

**Overview of the current research**

Norm-based coding has been attributed to human expertise with faces, including several face templates that aid in face perception. In the following empirical chapters, I examined reliance on norm-based coding, the potential to represent separate social categorical face templates, and how long manipulating social categorical face templates persisted. All of the following chapters are examined through a norm-based coding model of face perception and rely on exploring participant responses after viewing distorted face stimuli in some manner. In some studies, faces are distorted to appear more extreme than they should in real life; in other studies faces are expanded and contracted to utilize opposing aftereffects paradigms. Depending on how adults and children responded to distorted faces, it was possible to infer new information about norm-based coding and the malleable representation of our face space.

Chapter 2 examined children's reliance on norm-based coding for perceiving emotional facial expressions, and how this changed developmentally across 6 to 15 years of age. This chapter explored this question by utilizing an exaggerated expression paradigm (Rutherford & McIntosh, 2007; Walsh et al., 2014). Children made selections as to which of two faces appears the most like a realistic representation of an emotion. This paradigm used a continuum of increasingly exaggerated faces to examine this question and expected that if participants are relying on norm-based coding they should select less exaggerated faces. Through this paradigm, we examined children's reliance on emotion-based face templates during an emotion perception task. In experiment 1, 6-15-year-old children participated in this paradigm for happy and sad expressions. Our data demonstrated that with increasing age children became less tolerant of overly exaggerated faces, rejecting them as realistic representations of the emotions. In experiment 2, a new sample of 6–15-year-old children participated in the same paradigm for each of the basic emotions. The same pattern of results emerged. The work in chapter 2 demonstrated that children do not show an adult-like reliance on emotion-based face templates in childhood and that the reliance on norm-based coding for emotion perception is one that developed gradually into adolescence from 6 to 15 years of age.

Chapter 3 examined whether distinct face templates for Christian and Muslim faces are apparent in adults and 8-year-old children, a social category that had yet to be explored through an opposing aftereffects paradigm. This chapter controlled for and manipulated the two requirements for opposing aftereffects. Experiment 1 validated that the stimuli categories looked perceptually distinct (Short & Mondloch, 2010). In experiment 2 the social significance of the faces (Bestelmeyer et al., 2008; Jaquet et al., 2007) was manipulated in a novel way, through audio clips. Audio information about the faces was given during adaptation, to explore how this affected the manipulation of our face space. In experiment 2 we utilized an opposing aftereffects paradigm and adapted adult participants to Christian and Muslim expanded and contracted faces. Social significance was manipulated by applying religiously explicit audio descriptions to half of the participants during adaptation, and control audio to the other half of participants. In experiment 3 we created an adaptation storybook (Anzures et al., 2009; Short et al., 2011; 2014) and explored whether 8-year-old children show evidence of religious opposing aftereffects when told the religious groups the characters belong to. Through the following experiments, our data demonstrated the ability to evoke opposing aftereffects for Christian and Muslim faces in adults, but only when religiously explicit audio is received during adaptation. Adults without religiously explicit audio and 8-year-old children did not show evidence of separate face templates for Christian and Muslim faces. These experiments suggest that religion is another social category that can be represented as separate templates in face space but is dependent on how socially relevant it is to the individual. These results highlight the unique, experience-dependent nature of our face space in adults and children.

Chapter 4 examined 2 novel questions about opposing aftereffects paradigms and the representation of face space: 1) whether it is possible to adapt participants to face categories that vary based on race and sex, and 2) whether a diverse category of faces can be represented as a separate cognitive template than a non-diverse face set. Commonly during opposing aftereffects paradigms participants only adapt to two face categories that are distinctly different by one dimension (e.g., all White males and all White females). Adults underwent an opposing aftereffects paradigm that consisted of adapting to a diverse face set (consisting of male, female, White, Black, Latinx, and Asian faces) and a homogenous face set (only White males), that were contracted and expanded in opposite directions during adaptation. Opposing aftereffects were observed and revealed the ability to adapt to a diverse face set as a separate social category from a homogenous set. Diversity was a cue to category membership during adaptation, facilitating the separation of face templates. This was the first evidence that the diversity of faces can be considered relevant social information necessary for opposing aftereffects.

Chapter 5 explored how long the manipulation of face norms persists after an opposing aftereffects adaptation. Though opposing aftereffects are a powerful tool in exploring the representation of face templates, decay has yet to be examined like other forms of simple aftereffects. This chapter explored adaptation persistence or decay from an opposing aftereffects paradigm across 7 days. Adult participants underwent the same religious opposing aftereffects paradigm with the religious explicit audio as in Chapter 3. Participants were adapted during session 1, then return to the lab during session 2, 7 days later to be re-adapted to the same faces in the opposite direction. Participants were able to adapt in session 1 but not in session 2. Results revealed that the aftereffects from session 1 had interfered with the ability to re-adapt to the same faces in the opposite direction 7 days later.

Results suggested that religious opposing aftereffects may persist days after adaptation in the lab. As this is the first examination of the persistence of opposing aftereffects it is possible that adaptation through this paradigm may persist longer than simple aftereffects, and that the social relevance of the faces may affect adaptation persistence.

Chapter 6 summarizes the results from chapters 2 through 5. These experiments were conducted to further understand the reliance, development, representation, and manipulation of face templates in adults and children. The final chapter discusses the meaning of the results from the empirical chapters within the broader field of norm-based coding, visual adaptation, and face perception for adults and children. Theoretical connections and implications for children's developing face space and the effects of social reliance on face templates are highlighted. The limitations and future directions of this dissertation work are then discussed.

## References

Adams, W. J., Gray, K. L., Garner, M., & Graf, E. W. (2010). High-level face adaptation without awareness. *Psychological Science*, *21*(2), 205–210.

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Sciences*, *4*(7), 267–278.

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face Adaptation and Attractiveness Aftereffects in 8-Year-Olds and Adults. *Child Development*, *80*(1), 178–191.

Armann, R., Jeffery, L., Calder, A. J., & Rhodes, G. (2011). Race-specific norms for coding face identity and a functional role for norms. *Journal of Vision*, *11*(13), 9–9. https://doi.org/10.1167/11.13.9

Aylward, E. H., Park, J. E., Field, K. M., Parsons, A. C., Richards, T. L., Cramer, S. C., & Meltzoff, A. N. (2005). Brain Activation during Face Perception: Evidence of a Developmental Change. *Journal of Cognitive Neuroscience*, *17*(2), 308–319. https://doi.org/10.1162/0898929053124884

Baenninger, M. (1994). The Development of Face Recognition: Featural or Configurational Processing? *Journal of Experimental Child Psychology*, *57*(3), 377–396. https://doi.org/10.1006/jecp.1994.1018

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience*, *8*(6), 551–565.

Bentin, S., & Carmel, D. (2002). Accounts for the N170 face-effect: A reply to Rossion, Curran, & Gauthier. *Cognition*, *85*(2), 197–202.

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. https://doi.org/10.1080/13506280802708024

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review*, *94*(2), 115.

Brace, N. A., Hole, G. J., Kemp, R. I., Pike, G. E., Van Duuren, M., & Norgate, L. (2001). Developmental Changes in the Effect of Inversion: Using a Picture Book to Investigate Face Recognition. *Perception*, *30*(1), 85–94. https://doi.org/10.1068/p3059

Bruce, V., Campbell, R. N., Doherty-Sneddon, G., Langton, S., McAuley, S., & Wright, R. (2000). Testing face processing skills in children. *British Journal of Developmental Psychology*, *18*(3), 319–333. https://doi.org/10.1348/026151000165715

Carey, S., & Diamond, R. (1977). From piecemeal to configurational representation of faces. *Science*, *195*(4275), 312–314. https://doi.org/10.1126/science.831281

Carey, S., & Diamond, R. (1994). Are faces perceived as configurations more by adults than by children? *Visual Cognition*, *1*(2–3), 253–274.

Cassia, V. M., Kuefner, D., Picozzi, M., & Vescovo, E. (2009). Early Experience Predicts Later Plasticity for Face Processing: Evidence for the Reactivation of Dormant Effects. *Psychological Science*, *20*(7), 853–859. https://doi.org/10.1111/j.1467-9280.2009.02376.x

Chen, J., Yang, H., Wang, A., & Fang, F. (2010). Perceptual consequences of face viewpoint adaptation: Face viewpoint aftereffect, changes of differential sensitivity to face view, and their relationship. *Journal of Vision*, *10*(3), 12–12. https://doi.org/10.1167/10.3.12

Clifford, C. W. G., & Rhodes, G. (2005). *Fitting the Mind to the World: Adaptation and After-Effects in High-Level Vision*. OUP Oxford.

Cook, R., Matei, M., & Johnston, A. (2011). Exploring expression space: Adaptation to orthogonal and anti-expressions. *Journal of Vision*, *11*(4), 2–2. https://doi.org/10.1167/11.4.2

Damasio, A. R., Damasio, H., & Van Hoesen, G. W. (1982). Prosopagnosia: Anatomic basis and behavioral mechanisms. *Neurology*, *32*(4), 331–331.

de Heering, A., Houthuys, S., & Rossion, B. (2007). Holistic face processing is mature at 4 years of age: Evidence from the composite face effect. *Journal* *of Experimental Child Psychology*, *96*(1), 57–70. https://doi.org/10.1016/j.jecp.2006.07.001

De Sonneville, L. M. J., Verschoor, C. A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., & Vranken, M. (2002). Facial Identity and Facial Emotions: Speed, Accuracy, and Processing Strategies in Children and Adults. *Journal of Clinical and Experimental Neuropsychology*, *24*(2), 200–213. https://doi.org/10.1076/jcen.24.2.200.989

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General*, 107–117.

Durand, K., Gallay, M., Seigneuric, A., Robichon, F., & Baudouin, J.-Y. (2007). The development of facial emotion recognition: The role of configural information. *Journal of Experimental Child Psychology*, *97*(1), 14–27. https://doi.org/10.1016/j.jecp.2006.12.001

Eimer, M. (2011). The face-sensitivity of the n170 component. *Frontiers in Human Neuroscience*, *5*, 119.

Fairhall, S. L., & Ishai, A. (2007). Effective connectivity within the distributed cortical network for face perception. *Cerebral Cortex*, *17*(10), 2400–2406.

Farah, M. J., Levinson, K. L., & Klein, K. L. (1995). Face perception and within-category discrimination in prosopagnosia. *Neuropsychologia*, *33*(6), 661–674.

Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is" special" about face perception? *Psychological Review*, *105*(3), 482.

Fox, C. J., & Barton, J. J. S. (2007). What is adapted in face adaptation? The neural representations of expression in the human visual system. *Brain Research*, *1127*, 80–89. https://doi.org/10.1016/j.brainres.2006.09.104

Freire, A., & Lee, K. (2001). Face recognition in 4- to 7-year-olds: Processing of configural, featural, and paraphernalia information. *Journal of Experimental Child Psychology*, *80*(4), 347–371. https://doi.org/10.1006/jecp.2001.2639

Gao, X., & Maurer, D. (2009). Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions. *Journal of Experimental Child Psychology*, *102*(4), 503–521. https://doi.org/10.1016/j.jecp.2008.11.002

Gathers, A. D., Bhatt, R., Corbly, C. R., Farley, A. B., & Joseph, J. E. (2004). Developmental shifts in cortical loci for face and object recognition. *Neuroreport*, *15*(10), 1549–1553.

Gauthier, I., Behrmann, M., & Tarr, M. J. (1999). Can Face Recognition Really be Dissociated from Object Recognition? *Journal of Cognitive Neuroscience*, *11*(4), 349–370. https://doi.org/10.1162/089892999563472

Goffaux, V., & Rossion, B. (2006). Faces are "spatial"—Holistic face perception is supported by low spatial frequencies. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(4), 1023–1039. https://doi.org/10.1037/0096-1523.32.4.1023

Goldstein, A. G. (1965). Learning of inverted and normally oriented faces in children and adults. *Psychonomic Science*, *3*(1), 447–448. https://doi.org/10.3758/BF03343225

Grand, R. L., Mondloch, C. J., Maurer, D., & Brent, H. P. (2004). Impairment in holistic face processing following early visual deprivation. *Psychological Science*, *15*(11), 762–768.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, *4*(6), 223–233. https://doi.org/10.1016/S1364-6613(00)01482-0

Herba, C. M., Landau, S., Russell, T., Ecker, C., & Phillips, M. L. (2006). The development of emotion-processing in children: Effects of age, emotion, and intensity. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *47*(11), 1098–1106. https://doi.org/10.1111/j.1469-7610.2006.01652.x

Hochberg, J., & Galper, R. E. (1967). Recognition of faces: I. An exploratory study. *Psychonomic Science*, *9*(12), 619–620. https://doi.org/10.3758/BF03327918

Hoffman, E. A., Gobbini, M. I., & Haxby, J. V. (2000). *The distributed human neural system for face perception*.

Itier, R. J., & Taylor, M. J. (2004a). Face inversion and contrast-reversal effects across development: In contrast to the expertise theory. *Developmental Science*, *7*(2), 246–260. https://doi.org/10.1111/j.1467-7687.2004.00342.x

Itier, R. J., & Taylor, M. J. (2004b). N170 or N1? Spatiotemporal differences between object and face processing using ERPs. *Cerebral Cortex*, *14*(2), 132–142.

Jaquet, E., Rhodes, G., & Hayward, W. G. (2007). Opposite Aftereffects for Chinese and Caucasian Faces are Selective for Social Category Information and not Just Physical Face Differences. *Quarterly Journal of Experimental Psychology*, *60*(11), 1457–1467. https://doi.org/10.1080/17470210701467870

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Jeffery, L., McKone, E., Haynes, R., Firth, E., Pellicano, E., & Rhodes, G. (2010). Four-to-six-year-old children use norm-based coding in face-space. *Journal of Vision*, *10*(5), 18–18.

Jeffery, L., Read, A., & Rhodes, G. (2013). Four year-olds use norm-based coding for face identity. *Cognition*, *127*(2), 258–263.

Jeffery, L., Rhodes, G., McKone, E., Pellicano, E., Crookes, K., & Taylor, E. (2011). Distinguishing norm-based from exemplar-based coding of identity in children: Evidence from face identity aftereffects. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(6), 1824–1840. https://doi.org/10.1037/a0025643

Jenkins, R., Beaver, J. D., & Calder, A. J. (2006). I thought you were looking at me: Direction-specific aftereffects in gaze perception. *Psychological Science*, *17*(6), 506–513.

Jiang, F., Blanz, V., & O'Toole, A. J. (2006). Probing the Visual Representation of Faces With Adaptation: A View From the Other Side of the Mean. *Psychological Science*, *17*(6), 493–500. https://doi.org/10.1111/j.1467-9280.2006.01734.x

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience*, *17*(11), 4302–4311.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The Other-Race Effect Develops During Infancy: Evidence of Perceptual Narrowing. *Psychological Science*, *18*(12), 1084–1089. https://doi.org/10.1111/j.1467-9280.2007.02029.x

Kloth, N., Pugh, C., & Rhodes, G. (2017). The contributions of temporal delay and face exposure to the decay of gaze direction aftereffects. *Journal of Vision*, *17*(3), 5–5. https://doi.org/10.1167/17.3.5

Kloth, N., & Rhodes, G. (2016). Gaze direction aftereffects are surprisingly long-lasting. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(9), 1311.

Kloth, N., & Schweinberger, S. R. (2008). The temporal decay of eye gaze adaptation effects. *Journal of Vision*, *8*(11), 4–4. https://doi.org/10.1167/8.11.4

Köhler, W. (1924). *Die Physischen Gestalten in Ruhe Und Im Stationären Zustand*. Philosophische Akademie.

Leder, H., & Bruce, V. (2000). When Inverted Faces are Recognized: The Role of Configural Information in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *53*(2), 513–536. https://doi.org/10.1080/713755889

Leopold, D. A., Bondar, I. V., & Giese, M. A. (2006). Norm-based face encoding by single neurons in the monkey inferotemporal cortex. *Nature*, *442*(7102), 572–575.

Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature Neuroscience*, *4*(1), 89–94. https://doi.org/10.1038/82947

Leopold, D. A., Rhodes, G., Müller, K.-M., & Jeffery, L. (2005). The dynamics of visual adaptation to faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1566), 897–904. https://doi.org/10.1098/rspb.2004.3022

Lewis, M. (2004). Face-space-R: Towards a unified account of face recognition. *Visual Cognition*, *11*(1), 29–69. https://doi.org/10.1080/13506280344000194

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Loffler, G., Yourganov, G., Wilkinson, F., & Wilson, H. R. (2005). FMRI evidence for the neural representation of faces. *Nature Neuroscience*, *8*(10), 1386–1391.

MacLin, O. H., & Webster, M. A. (2001). Influence of adaptation on the perception of distortions in natural images. *Journal of Electronic Imaging*, *10*(1), 100–109. https://doi.org/10.1117/1.1330573

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, *6*(6), 255–260.

McKone, E., & Boyer, B. L. (2006). Sensitivity of 4-year-olds to featural and second-order relational changes in face distinctiveness. *Journal of Experimental Child Psychology*, *94*(2), 134–162. https://doi.org/10.1016/j.jecp.2006.01.001

McKone, E., & Robbins, R. (2011). Are faces special. *Oxford Handbook of Face Perception*, 149–176.

Michel, C., Rossion, B., Han, J., Chung, C.-S., & Caldara, R. (2006). Holistic processing is finely tuned for faces of one's own race. *Psychological Science*, *17*(7), 608–615.

Mondloch, C. J., Geldart, S., Maurer, D., & Le Grand, R. (2003). Developmental changes in face processing skills. *Journal of Experimental Child Psychology*, *86*(1), 67–84.

Mondloch, C. J., Grand, R. L., & Maurer, D. (2002). Configural Face Processing Develops more Slowly than Featural Face Processing. *Perception*, *31*(5), 553–566. https://doi.org/10.1068/p3339

Mondloch, C. J., Leis, A., & Maurer, D. (2006). Recognizing the face of Johnny, Suzy, and me: Insensitivity to the spacing among features at 4 years of age. *Child Development*, *77*(1), 234–243.

Mondloch, C. J., Pathman, T., Maurer, D., Le Grand, R., & de Schonen, S. (2007). The composite face effect in six-year-old children: Evidence of adult-like holistic face processing. *Visual Cognition*, *15*(5), 564–577. https://doi.org/10.1080/13506280600859383

Nichols, D. F., Betts, L. R., & Wilson, H. R. (2010). Decoding of faces and face components in face-sensitive human visual cortex. *Frontiers in Psychology*, *1*, 28.

Nishimura, M., Maurer, D., & Gao, X. (2009). Exploring children's face-space: A multidimensional scaling analysis of the mental representation of facial identity. *Journal of Experimental Child Psychology*, *103*(3), 355–375. https://doi.org/10.1016/j.jecp.2009.02.005

Nishimura, M., Maurer, D., Jeffery, L., Pellicano, E., & Rhodes, G. (2008). Fitting the child's mind to the world: Adaptive norm-based coding of facial identity in 8-year-olds. *Developmental Science*, *11*(4), 620–627.

Passarotti, A. M., Paul, B. M., Bussiere, J. R., Buxton, R. B., Wong, E. C., & Stiles, J. (2003). The development of face and location processing: An fMRI study. *Developmental Science*, *6*(1), 100–117. https://doi.org/10.1111/1467-7687.00259

Pellicano, E., & Rhodes, G. (2003). Holistic Processing of Faces in Preschool Children and Adults. *Psychological Science*, *14*(6), 618–622. https://doi.org/10.1046/j.0956-7976.2003.psci_1474.x

Pellicano, E., Rhodes, G., & Peters, M. (2006). Are preschoolers sensitive to configural information in faces? *Developmental Science*, *9*(3), 270–277. https://doi.org/10.1111/j.1467-7687.2006.00489.x

Pitcher, D., Walsh, V., & Duchaine, B. (2011). The role of the occipital face area in the cortical face perception network. *Experimental Brain Research*, *209*(4), 481–493.

Reed, C. L., Stone, V. E., Bozova, S., & Tanaka, J. (2003). The Body-Inversion Effect. *Psychological Science*, *14*(4), 302–308. https://doi.org/10.1111/1467-9280.14431

Rhodes, G., & Jeffery, L. (2006). Adaptive norm-based coding of facial identity. *Vision Research*, *46*(18), 2977–2987.

Rhodes, G., Jeffery, L., Clifford, C. W., & Leopold, D. A. (2007). The timecourse of higher-level face aftereffects. *Vision Research*, *47*(17), 2291–2296.

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., & Nakayama, K. (2003). Fitting the Mind to the World: Face Adaptation and Attractiveness Aftereffects. *Psychological Science*, *14*(6), 558–566.

Rhodes, G., & Leopold, D. A. (2011). Adaptive norm-based coding of face identity. *The Oxford Handbook of Face Perception*, 263–286.

Rhodes, G., Pond, S., Jeffery, L., Benton, C. P., Skinner, A. L., & Burton, N. (2017). Aftereffects support opponent coding of expression. *Journal of Experimental Psychology: Human Perception and Performance*, *43*(3), 619–628. https://doi.org/10.1037/xhp0000322

Rhodes, G., Robbins, R., Jaquet, E., McKone, E., Jeffery, L., & Clifford, C. W. (2005). Adaptation and face perception: How aftereffects implicate norm-based coding of faces. *Fitting the Mind to the World: Adaptation and after-Effects in High-Level Vision*, 213–240.

Rhodes, G., & Tremewan, T. (1996). Averageness, Exaggeration, and Facial Attractiveness. *Psychological Science*, *7*(2), 105–110. JSTOR.

Robbins, R., McKone, E., & Edwards, M. (2007). Aftereffects for face attributes with different natural variability: Adapter position effects and neural models. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(3), 570–592. https://doi.org/10.1037/0096-1523.33.3.570

Rossion, B., Gauthier, I., Tarr, M. J., Despland, P., Bruyer, R., Linotte, S., & Crommelinck, M. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: An electrophysiological account of face-specific processes in the human brain. *Neuroreport*, *11*(1), 69–72.

Rutherford, M. D., Chattha, H. M., & Krysko, K. M. (2008). *The use of aftereffects in the study of relationships among emotion categories*.

Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus Prototype Matching: Strategies of Perception of Emotional Facial Expressions in the Autism Spectrum. *Journal of Autism and Developmental Disorders*, *37*(2), 187–196. https://doi.org/10.1007/s10803-006-0151-9

Sangrigoli, S., & Schonen, S. D. (2004). Recognition of own-race and other-race faces by three-month-old infants. *Journal of Child Psychology and Psychiatry*, *45*(7), 1219–1227. https://doi.org/10.1111/j.1469-7610.2004.00319.x

Scherf, K. S., Behrmann, M., Humphreys, K., & Luna, B. (2007). Visual category-selectivity for faces, places and objects emerges along different developmental trajectories. *Developmental Science*, *10*(4), F15–F30. https://doi.org/10.1111/j.1467-7687.2007.00595.x

Schwarzer, G. (2000). Development of Face Processing: The Effect of Face Inversion. *Child Development*, *71*(2), 391–401.

Schweinberger, S. R., Zäske, R., Walther, C., Golle, J., Kovács, G., & Wiese, H. (2010). Young without plastic surgery: Perceptual adaptation to the age of female and male faces. *Vision Research*, *50*(23), 2570–2576. https://doi.org/10.1016/j.visres.2010.08.017

Short, L. A., Hatry, A. J., & Mondloch, C. J. (2011). The development of norm-based coding and race-specific face prototypes: An examination of 5-and 8-year-olds' face space. *Journal of Experimental Child Psychology*, *108*(2), 338–357.

Short, L. A., Lee, K., Fu, G., & Mondloch, C. J. (2014). Category-specific face prototypes are emerging, but not yet mature, in 5-year-old children. *Journal of Experimental Child Psychology*, *126*, 161–177. https://doi.org/10.1016/j.jecp.2014.04.004

Short, L. A., & Mondloch, C. J. (2010). The Importance of Social Factors is a Matter of Perception. *Perception*, *39*(11), 1562–1564. https://doi.org/10.1068/p6758

Skinner, A. L., & Benton, C. P. (2010). Anti-Expression Aftereffects Reveal Prototype-Referenced Coding of Facial Expressions. *Psychological Science*, *21*(9), 1248–1253. https://doi.org/10.1177/0956797610380702

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology*, *46*(2), 225–245. https://doi.org/10.1080/14640749308401045

Tanaka, James W., Kay, J. B., Grinnell, E., Stansfield, B., & Szechter, L. (1998). Face Recognition in Young Children: When the Whole is Greater than the Sum of Its Parts. *Visual Cognition*, *5*(4), 479–496. https://doi.org/10.1080/713756795

Taylor, M. J., Edmonds, G. E., McCarthy, G., & Allison, T. (2001). Eyes first! Eye processing develops before face processing in children. *NeuroReport*, *12*(8), 1671–1676.

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology*, *79*(4), 471–491. https://doi.org/10.1111/j.2044-8295.1988.tb02747.x

Valentine, T. (1991). A Unified Account of the Effects of Distinctiveness, Inversion, and Race in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *43*(2), 161–204. https://doi.org/10.1080/14640749108400966

Valentine, T., Darling, S., & Donnelly, M. (2004). Why are average faces attractive? The effect of view and averageness on the attractiveness of female faces. *Psychonomic Bulletin & Review*, *11*(3), 482–487. https://doi.org/10.3758/BF03196599

Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A Century of Gestalt Psychology in Visual Perception I. Perceptual Grouping and Figure-Ground Organization. *Psychological Bulletin*, *138*(6), 1172–1217. https://doi.org/10.1037/a0029333

Walsh, J. A., Vida, M. D., & Rutherford, M. D. (2014). Strategies for Perceiving Facial Expressions in Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *44*(5), 1018–1026. https://doi.org/10.1007/s10803-013-1953-1

Watson, T. L., & Clifford, C. W. (2003). Pulling faces: An investigation of the face-distortion aftereffect. *Perception*, *32*(9), 1109–1116.

Watson, T. L., & Clifford, C. W. G. (2006). Orientation dependence of the orientation-contingent face aftereffect. *Vision Research*, *46*(20), 3422–3429. https://doi.org/10.1016/j.visres.2006.03.026

Webster, M. A. (2011). Adaptation and visual coding. *Journal of Vision*, *11*(5), 3–3. https://doi.org/10.1167/11.5.3

Webster, Michael A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature*, *428*(6982), 557. https://doi.org/10.1038/nature02420

Webster, Michael A., & Maclin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review*, *6*(4), 647–653. https://doi.org/10.3758/BF03212974

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, *81*(1), 141–145. https://doi.org/10.1037/h0027474

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception*, *16*(6), 747–759. https://doi.org/10.1068/p160747

Yovel, G. (2009). The shape of facial features and the spacing among them generate similar inversion effects: A reply to Rossion (2008). *Acta Psychologica*, *132*(3), 293–299. https://doi.org/10.1016/j.actpsy.2009.07.009

Yovel, G., Pelc, T., & Lubetzky, I. (2010). It's all in your head: Why is the body inversion effect abolished for headless bodies? *Journal of Experimental Psychology: Human Perception and Performance*, *36*(3), 759–767. https://doi.org/10.1037/a0017451

# Chapter 2:

# The Development of Template-Based Facial Expression Perception from 6 to 15 Years of Age

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## Preface

The ability to quickly and accurately perceive relevant information from faces is an important social-cognitive skill in humans. Some of the expertise adults have with faces has been attributed to norm-based coding, referring to a cognitive representation of a face to aid in perception (Valentine, 1991). Previous research has indicated that adults have several social categorical face norms, for example, race (Bestelmeyer et al., 2010; Jaquet et al., 2008; Little et al., 2008), sex (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Little et al., 2008; Schweinberger et al., 2010; Watson & Clifford, 2006), and emotional expression (Bestelmeyer et al., 2010; Cook et al., 2011; Rhodes et al., 2017; Skinner & Benton, 2010). Face norms develop based on our experience with faces, and are a reflection of the faces we see day to day (Rhodes et al., 2003; Webster, 2011, Webster & Maclin, 1999).

Previous work has supported the hypothesis that adults rely on a norm-based template-matching strategy when perceiving emotional facial expressions

(Walsh et al., 2014). This has been examined through the use of an exaggerated expression paradigm (Rutherford & McIntosh, 2007; Walsh et al., 2014). Through this paradigm, participants are asked which face looks like how a real person looks when they are feeling an emotion from a pair of faces, one of which is always more exaggerative. The paradigm predicts that if participants are relying on a norm-based emotion perception strategy they should select the less exaggerative face. This is predicted because face norms should reflect faces we have experienced, and the exaggerated expressions in this paradigm are along an increasingly unrealistic trajectory. From examining differences between typically developed adults and adults with Autism Spectrum Disorder (ASD) previously, typically developed adults are more likely to reject overly exaggerated faces as a realistic representation of emotions (Rutherford & McIntosh, 2007; Walsh et al., 2014).

Children's emotion perception skills have been found to develop gradually, making more errors than adults on various face perception tasks (Bruce et al., 2000; Freire & Lee, 2001; Mondloch et al., 2002, 2003). With this known, the goal of this chapter was to explore children's reliance on norm-based emotion perception strategies and how they develop from 6-15-years-old. In experiment 1, 6-15-year-old children completed the same methods as Walsh et al. (2014), examining the perception of happiness and sadness through the exaggerated expression paradigm. Children's reliance on a norm-based template-matching strategy was found to improve from 6-15 years of age. Younger children were more likely to select the more exaggerated emotion as a realistic representation than older children, with the selection of the more exaggerated face decreasing with age.

In experiment 2 a new continuum of exaggerated faces was created to examine this question across each of the basic emotions: happiness, sadness, anger, fear, surprise, and disgust. A new sample of 6–15-year-old children completed the exaggerated expression paradigm for each of the basic emotions. With new stimuli and a new sample, the same pattern of results emerged. Younger children are more likely to select the more exaggerative expression as a realistic representation of an emotion and decrease in doing so with age.

The implication of this chapter suggested that some of the immaturity children have with emotion perception could be due to developing reliance on norm-based coding. In both experiments, children do not show an adult-like reliance on norm-based emotion perception strategies. Adult's reliance on norm-based coding is an important perceptual skill related to their expertise with faces. Reliance on norm-based coding for emotion perception was found to be a skill that develops gradually into adolescence from 6 to 15 years of age.

## References

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. https://doi.org/10.1080/13506280802708024

Bruce, V., Campbell, R. N., Doherty-Sneddon, G., Langton, S., McAuley, S., & Wright, R. (2000). Testing face processing skills in children. *British Journal of Developmental Psychology*, *18*(3), 319–333. https://doi.org/10.1348/026151000165715

Cook, R., Matei, M., & Johnston, A. (2011). Exploring expression space: Adaptation to orthogonal and anti-expressions. *Journal of Vision*, *11*(4), 2–2. https://doi.org/10.1167/11.4.2

Freire, A., & Lee, K. (2001). Face recognition in 4- to 7-year-olds: Processing of configural, featural, and paraphernalia information. *Journal of Experimental Child Psychology*, *80*(4), 347–371. https://doi.org/10.1006/jecp.2001.2639

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Mondloch, C. J., Geldart, S., Maurer, D., & Le Grand, R. (2003). Developmental changes in face processing skills. *Journal of Experimental Child Psychology*, *86*(1), 67–84.

Mondloch, C. J., Grand, R. L., & Maurer, D. (2002). Configural Face Processing Develops more Slowly than Featural Face Processing. *Perception*, *31*(5), 553–566. https://doi.org/10.1068/p3339

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., & Nakayama, K. (2003). Fitting the Mind to the World: Face Adaptation and Attractiveness Aftereffects. *Psychological Science*, *14*(6), 558–566.

Rhodes, G., Pond, S., Jeffery, L., Benton, C. P., Skinner, A. L., & Burton, N. (2017). Aftereffects support opponent coding of expression. *Journal of*

*Experimental Psychology: Human Perception and Performance*, *43*(3), 619–628. https://doi.org/10.1037/xhp0000322

Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus Prototype Matching: Strategies of Perception of Emotional Facial Expressions in the Autism Spectrum. *Journal of Autism and Developmental Disorders*, *37*(2), 187–196. https://doi.org/10.1007/s10803-006-0151-9

Schweinberger, S. R., Zäske, R., Walther, C., Golle, J., Kovács, G., & Wiese, H. (2010). Young without plastic surgery: Perceptual adaptation to the age of female and male faces. *Vision Research*, *50*(23), 2570–2576. https://doi.org/10.1016/j.visres.2010.08.017

Skinner, A. L., & Benton, C. P. (2010). Anti-Expression Aftereffects Reveal Prototype-Referenced Coding of Facial Expressions. *Psychological Science*, *21*(9), 1248–1253. https://doi.org/10.1177/0956797610380702

Valentine, T. (1991). A Unified Account of the Effects of Distinctiveness, Inversion, and Race in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *43*(2), 161–204. https://doi.org/10.1080/14640749108400966

Walsh, J. A., Vida, M. D., & Rutherford, M. D. (2014). Strategies for Perceiving Facial Expressions in Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *44*(5), 1018–1026. https://doi.org/10.1007/s10803-013-1953-1

Watson, T. L., & Clifford, C. W. G. (2006). Orientation dependence of the orientation-contingent face aftereffect. *Vision Research*, *46*(20), 3422–3429. https://doi.org/10.1016/j.visres.2006.03.026

Webster, M. A. (2011). Adaptation and visual coding. *Journal of Vision*, *11*(5), 3–3. https://doi.org/10.1167/11.5.3

Webster, Michael A., & Maclin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review*, *6*(4), 647–653. https://doi.org/10.3758/BF03212974

**Abstract**

When perceiving emotional facial expressions, adults use a template-matching strategy, comparing the perceived face to a stored representation. A rejection of unnaturally exaggerated faces is characteristic of this strategy since the exaggerated expressions do not match the stored template. In contrast, a rule-based perceptual strategy (e.g., wide eyes indicate surprise) would be more tolerant of exaggeration. The current study uses exaggeration tolerance to test the expression perception strategies of children from 6 to 15 years of age. In Experiment 1, 62 (38 male) participants viewed pairs of happy or sad faces varying in exaggeration and selected the face that looked closest to how a happy (or sad) person really looks. With age, children became less likely to choose the more exaggerated expression. In Experiment 2 this result was replicated with each of the 6 basic emotions. Sixty-six children (26 male, 50 Caucasian, 10 mixed-race, 4 Indian, 2 unidentified) from 6 to 15 years of age completed the same experimental tasks as Experiment 1 for all 6 emotions. Again, with age children became less likely to choose the more exaggerated face. The results from both experiments suggest that the development of an adult-like template-matching strategy lasts into adolescence.

***Keywords:*** *face perception; expression perception; perceptual strategies; template-matching*

## Introduction

Adults can quickly discriminate emotional facial expressions, even when viewing a static display. The norm-based coding model of facial expression perception suggests that emotion expressions are perceived when the stimulus face is compared to a stored template of the expression (Burton et al., 2013; Cook et al., 2011; Rhodes et al., 2017; Skinner & Benton, 2010). Identity, gender, and race are also thought to be visually coded using this norm-based coding strategy (Jaquet et al., 2008; Little et al., 2005; Rhodes et al., 2011; Rhodes & Leopold, 2011).

Adaptation results from reduced activity in the neurons responding to a stimulus after repeated exposure or continuous viewing (Barlow & Hill, 1963; Bednar & Miikkulainen, 2000). Visual adaptation consists of a distortion in perception following a prolonged exposure to a stimulus (Clifford & Rhodes, 2005; Webster, 2011), and this distortion is called an aftereffect. Specifically, an aftereffect means perceiving a neutral stimulus as the opposite of the adapted stimulus. For example, after adapting to faces that have their features distorted so that they are contracted inward, viewing an undistorted face will appear as if the features are expanded outward (Rhodes et al., 2003; Webster & Maclin, 1999). Though aftereffects may be misperceptions, they have been frequently used as an experimental technique in understanding perception and are commonly used to explore the cognitive representation of face space (see Clifford & Rhodes, 2005; Webster, 2011 for reviews). Aftereffects provide evidence for the norm-based coding of faces and have been observed for face orientation (Rhodes et al., 2004), age (Short et al., 2015) and species (Little et al., 2008).

**Norm-based coding of facial expressions**

Aftereffect paradigms have been used to demonstrate that adults use norm-based coding when perceiving emotional facial expressions (Burton et al., 2015; Burton et al., 2013; Cook et al., 2011). One way of evoking expression aftereffects in the laboratory is by creating a continuum of expressions ranging from the prototypical exemplar (e.g., surprise with open mouth and eyes and raised eyebrows) to the physical opposite (e.g., narrow mouth and eyes and lowered eyebrows). Such physically inverted expressions are sometimes called "anti-expressions". An anti-expression is physically distinct from a neutral expression to the same extent that the prototypical facial expression is distinct from the average (e.g., if eyebrows are more upwards for happiness, then the anti-expression of happiness would have downward eyebrows, and the distance from neutral is the same). These anti-expressions are created via face-morphing software, by calculating each point on the facial expression that is distanced from a neutral face and moving it in the opposite direction from the neutral face (Skinner & Benton, 2010, 2012). The continuum includes more intense and less intense anti-expressions. Adaptation occurs if after viewing an anti-expression there is a shift in the prototype of that expression, altering perception immediately after adaptation. For example, after adapting to an anti-expression for fear, neutral faces appear to have fearful expressions (Burton et al., 2013). This shift is often measured by comparing results of participants selecting which emotional facial expression is most noticeable when viewing a neutral face from pre- to post-adaptation trials (e.g., adapt to anti-fearful and neutral faces now appear more like a fearful expression after adaptation). If participants show a significant change from pre- to post-adaptation, this is evidence of an aftereffect (Burton et al., 2016).

Research using this paradigm has provided evidence that people use norm-based coding in perceiving the six basic emotions – happiness, sadness, fear, anger, disgust, and surprise– (Skinner & Benton, 2010, 2012; see also Cook et al., 2011). Adults have larger aftereffects for those anti-expressions that are stronger in intensity, which is evidence of a norm-based model. Additionally, children as young as nine-years-old have shown evidence of norm-based coding of facial expressions through adaptation aftereffects (Burton et al., 2013).

An alternative to norm-based coding is exemplar-based coding. This view posits that the stimulus is compared to a stored representation of a single exemplar (Ross et al., 2014), but that this exemplar holds no specific special significance. Additionally, while the norm-based coding model predicts larger aftereffects when adapting to more intense stimuli, an exemplar-based model does not. There is some recent evidence through the use of Support Vector Machines (SVM) and Artificial Neural Networks (ANN) that facial expression recognition may also utilize an exemplar-based model (Farajzadeh & Hashemzadeh, 2018; Shang & Chan, 2008). By extracting the most informative features of a face it is possible to recognize different facial expressions. Unlike norm-based coding, exemplar-based coding relies on how similar a test face is to the norm rather than how much it deviates. Depending on the research question, face and emotion perception may be examined through both norm-based and exemplar-based models. Evidence for both exemplar-based and norm-based coding of identity has previously been observed. (Jeffery et al., 2011; Ross et al., 2014).

**Experimentally Discriminating Template Matching from Rule-Based Perceptual Strategies**

Neurotypical adults commonly use a template-matching strategy when perceiving facial expressions, whereas adults with ASD use a rule-based strategy when perceiving expressions (Rutherford & McIntosh, 2007; Walsh et al., 2014). The rule-based strategy involves perceiving expressions using explicit rules for how facial features appear for each expression, e.g., raised eyebrows, open mouth. Template-matching relies on comparing a face to a stored representation of an average of faces seen throughout one's lifetime (Rutherford & McIntosh, 2007; Walsh, et al, 2014).

A paradigm that compares a template-matching strategy to a rule-based strategy consists of presenting observers with increasingly exaggerated expressions and asking them to select a realistic example of the expression (Rutherford & McIntosh, 2007; Walsh et al. 2014). If expression perception depends on a template-matching strategy, realistically exaggerated expressions would match the template, but unnaturally exaggerated expressions would be an unrealistic representation of the expression. Conversely, tolerance of the unnaturally exaggerated expression is consistent with a rule-based strategy since the rule such as “raised eyebrows” or “upturned mouth” is still true.

Evidence of tolerance for exaggeration is when participants are more likely to select exaggerated expressions as a representation as to how that emotion appears in real life over less exaggerated expressions. Participants who accept extremely exaggerated representations of an expression are tolerating the unrealistic distortion. Observers’ rejection of the intensely exaggerated expression as a realistic representation of that expression would be consistent with a template-matching strategy as the faces should no longer appear realistic and would not match a norm-based template formed by faces seen in day-to-day life. Therefore, by examining tolerance for exaggerated expressions, relative to examining the ability to reject overly exaggerated faces, it is possible to discriminate template matching from rule-based perceptual strategies.

Rutherford and McIntosh (2007) examined tolerance for exaggeration of the six basic expressions in adults with autism spectrum disorder (ASD), comparing their results with neurotypical adults. Illustrations of expressions varied from unaltered to “exaggerated” (twice the physical difference between neutral and average) and “double-exaggerated” (four times the difference). Participants saw pairs of illustrations of the same expression, varying in exaggeration, and were asked to select the face that looked “how a real person would look” while expressing the given expression. Participants with ASD selected a higher proportion of exaggerated faces as representations of emotions compared to neurotypical adult controls, indicating that they had a higher tolerance for exaggeration.

Walsh et al. (2014) extended this paradigm, using more ecologically valid face stimuli and additional control conditions. The stimuli consisted of composite images derived from photographs of real people displaying happy and sad emotional expressions. Expressions were extrapolated using morphing software to create 5 images of each expression, one that was unaltered, and four more of each expression that was increasingly exaggerated. Participants followed a similar procedure as those in Rutherford and McIntosh (2007), selecting the face that looked the most like a person looks in real life when feeling happy or sad. Consistent with Rutherford and McIntosh (2007), adults with ASD selected a higher proportion of exaggerated faces, suggesting the use of a rule-based strategy and higher tolerance for exaggeration.

**Expression perception development in children**

Emotion expression perception emerges early but develops gradually through childhood and into adolescence (De Sonneville et al., 2002; Gao & Maurer, 2010; Herba, Landau, Russell, Ecker, & Phillips, 2006; Chronaki, Hadwin, Garner, Maurage, & Sonuga-Barke, 2015; Durand, Gallay, Seigneuric, Rodger, Vizioli, Ouyang, 2015). Evidence suggests that the trajectory of emotion perception recognition varies based on the emotion. The recognition of happiness consistently develops earlier than other emotional expressions (Boyatzis, Chazan,

& Ting, 1993; Durand et al., 2007; Gosselin, 1995; Gosselin, 2005; Gosselin & Larocque, 2000), while fear, anger, and disgust are recognized later into childhood (Chronaki, et al, 2015; Durand et al., 2007, Rodger, Vizioli, & Ouyang, 2015), though the order of recognition for each of these emotions is not always consistent. Some studies indicate that sadness and anger are the next recognized developmentally (Herba & Phillips, 2004; Widen, 2013). Other studies suggest that sadness and anger are the least accurately recognized in childhood (Montirosso, Peverelli, Frigerio, Crespi, & Borgatti, 2010). Some studies report that sadness is recognized as early as happiness (Boyatzis, Chazan, & Ting, 1993; Gosselin, 2005; Gosselin & Larocque, 2000), while others suggest sadness develops more gradually (Chronaki, et al, 2015; Durand et al., 2007, Rodger, Vizioli, Ouyang, 2015).

Recognition of different emotions may also develop at different times based on how the child makes use of information to inform behaviour, and which emotions are most relevant to them (Lee, Cheal, & Rutherford, 2015; Lee, DaSilva, & Rutherford, 2020). For example, it may be more adaptive for a child to be able to recognize fear or anger earlier than sadness or disgust because they could formulate a functional behavioral response to the former but not the latter. This could affect the timing of recognizing some negative emotions over others. Infants were found to respond more strongly to their mother's fear or anger response as a social reference than sadness (Sorce et al., 1985). Additionally, differences in methodologies and task demands could lead to differences in results across studies. The ability to express an emotion, recognize an emotion, and accurately label an emotion are all quite different tasks, which could affect differing results (Bruce, Campbell, Doherty-Sneddon, Langton, McAuley, & Wright, 2000). Though despite trajectory differences in emotion children's recognition performance generally improves with age.

**Children's reliance on expression intensity and facial features**

Differences between children's and adults' emotion perception recognition may be due to differences in the strategies they utilize. In examining children's accuracy in recognizing expressions at various intensities (Hess, Blairy, & Kleck, 1997), children required stronger intensities of expressions than adults do in order to accurately identify them (Gao & Maurer, 2009; Herba et al., 2006). Younger children are also more likely to use expression intensity as a cue to emotion authenticity than older children or adults (Dawel, et al, 2015; Del Giudice & Colle, 2007; Thibault, Gosselin, Brunel, & Hess, 2009). According to a norm-based view, children may have difficulties perceiving less intense expressions because their stored representations of facial expressions are less developed than those of adults (De Sonneville et al., 2002). Evidence of children's reliance on emotional intensity supports the hypothesis that children's template-matching strategy may take extended time to develop to an adult-like perceptual strategy.

Children may also differ from adults on emotion perception tasks due to relying less on configural face processing than adults (Del Giudice & Colle, 2007; Gosselin et al., 2002; Leder & Bruce, 1998; Tanaka & Farah, 1993; Thompson, 1980). Carey and Diamond (1977) suggest that children do not use configural information until 10 years of age. Instead, children may use a feature-based strategy to emotion perception. Seven-year-olds appear to perceive faces based on individual features and not the relationship between the features (Schwarzer, 2000) as adults do. A rule-based strategy of emotion perception would rely more on features and dependence on this information may influence children to rely on such a strategy. While there is evidence that configural processing develops more slowly than featural processing (Carey & Diamond, 1977; Schwarzer, 2000) there is also some evidence suggesting that holistic processing and configural processing may develop earlier than was previously thought (Crookes & McKone, 2009).

**Current Studies**

While neurotypical adults are believed to use a template-matching strategy when perceiving emotional facial expressions (Rutherford & McIntosh, 2007; Walsh et al., 2014) it is not clear which strategies children use nor when the template-matching strategy develops. The purpose of the current studies is to explore the developmental trajectory of a template-matching strategy of emotion perception from 6 to 15 years of age. Experiment 1 aims to replicate the methodology used by Walsh et al. (2014) examining the developmental trajectory of template-matching for happiness and sadness. Happiness and sadness were examined first as some consider them be the initial expression categories children understand (see Widen, 2013 for a review) and adult models were chosen so that we could replicate the findings of Walsh et al. (2014). Experiment 2 aims to expand upon Experiment 1 by examining the developmental trajectory of the template-matching strategy for each of the basic emotions: happiness, sadness, anger, fear, surprise, and disgust using a similar methodology.

A rule-based strategy is consistent with more tolerance of exaggeration because extremely raised eyebrows (or an extremely wide mouth) still conform with the rule "raise eyebrows" (or "open mouth"). In contrast, a template-matching strategy would be less tolerant for exaggeration because at some level of exaggeration would no longer match the template, and may appear grotesque (Rutherford & McIntosh, 2007; Walsh et al. 2014). It is hypothesized that in Experiment 1 and 2, age will be negatively related to tolerance for exaggeration in the expression perception tasks but not the control tasks, consistent with the development of a template-matching strategy for emotion perception. This would suggest that younger children tolerate the exaggerated representations of expressions as realistic representations of those emotions, while older children do not.

The same pattern of results is not expected to be observed in the control task, despite identical physical stimuli, because the control task does not ask about the emotionality of the faces. The control task asks about how realistic a face appears, a more general face perception task that does not involve emotion perception. It is hypothesized that the perceptual processes engaged by these two tasks would differ. If participants are utilizing a rule-based strategy in perceiving the emotion of a face, this should be unaffected by the ability to perceive how realistic a face is as the rules for how features appear while expressing an emotion should no longer be relevant to perceiving how realistic a face appears overall. Previous research has indicated adult-like expression perception performance develops by around 16 years (Dawel et al., 2015; Del Giudice & Colle, 2007; Gosselin, Beaupré, & Boissonneault, 2002; Thibault et al., 2009). However, as children's ability to recognize and accurately label each of the basic emotions differs across emotion type with age (Widen, 2013) it is possible that some of the emotions examined in Experiment 2 may differ from each other based on their relationship between age and tolerance for exaggeration.

## Experiment 1: The development of template-matching for happiness and sadness

Experiment 1 is designed to examine whether children develop a template-matching emotion perception strategy while perceiving happiness and sadness across ages 6-15. The maximum age of 15 was selected following Herba and colleagues (Herba et al., 2006) who found developmental changes from 4-15 years of age in children's reliance on emotion intensity for emotion perception. The minimum age of 6 years ensured all participants were able to complete the Wechsler Intelligence Scale for Children (WISC) (Wechsler, 2003). Performance on the WISC was used as inclusion criterion in order to exclude children who were not developing typically.

Experiment 1 used a similar methodology as Walsh et al. (2014) examining only happiness and sadness. Children viewed images from a continuum of 5 levels of exaggeration and completed expression perception and face perception tasks. Children were presented with two faces of the same emotion, one of which was more exaggerated than the other. Tolerance for exaggeration, how frequently participants select the more exaggerated face as a realistic representation of that emotion, was compared across the Emotions tasks (the experimental task) and the Realism tasks (the control task). It is hypothesized that age would be negatively related to tolerance for exaggeration on the Emotions task for both happiness and sadness. It is anticipated that younger children will make selections differently on the Emotions task than the Realism task and will respond differently from older children.

## Methods

### Participants

Sixty-seven children participated. Informed consent was obtained from parents on the behalf of their child, and verbal assent was obtained from all participants. All families were recruited using a database of information from parents who have agreed to participate in research in the Hamilton area. A sensitivity power analysis, or post-hoc power analysis, is a power analysis computed after the study is conducted to generate an expected minimum effect size that the collected sample could detect (O'Keefe, 2007). A sensitivity power analysis revealed that a sample of $N = 67$ had 80% power to detect a relationship between age and tolerance for exaggerations of $d$ = .30 or greater, encompassing the ability to detect effect sizes as reported by Gao and Maurer (2010) for happy ($d$= .9) and sad ($d$=1.2).

Participants had to get 75% correct on the practice trials with a maximum of 3 attempts to be included in analyses. All participants did. Participants had to get 70% correct on the Discrimination task to be included in analyses. All participants did. The other exclusion criterion was  Full Scale Intelligence Quotient (FSIQ) on the WISC-IV (Wechsler, 2003), participants with scores of less than 70, were excluded in order to exclude atypical cognitive development. Four children were excluded for not meeting this criterion. One additional participant who only selected the most exaggerated faces in all trials was identified as an extreme when visualizing a boxplot, as it was beyond 3 interquartile ranges (IQR) from the end of the box. This participant was excluded as an outlier.[1] Sixty-two children ranging from 6 to 15 years old ($M$ = 10.45, $SD$ = 3.01) were included in the analyses, 38 of which were males. The sample comprised 10 six-year-olds, 5 seven-year-olds, 5 eight-year-olds, 4 nine-year-olds, 3 ten-year-olds, 10 eleven-year-olds, 3 twelve-year-olds, 12 thirteen-year-olds, 5 fourteen-year-olds, and 5 fifteen-year-olds.

Participants were recruited from a database of children whose parents had previously indicated their interest in participating in research. The database is

[1] Main analyses for tolerance for exaggeration in the Emotions and Realism task remained significant with the outlier included Emotions ($r$ (63) = -0.50, $p$ =<0.001), Realism ($r$ (63) = -0.41, $p$ =0.001).

collected from parents in major hospitals in Hamilton, Ontario, Canada. Ethics was obtained through McMaster's research ethics board. Participants received an honorarium of $15 for participation in the study.

**Materials**

The photoset consisted of the same stimuli used by Walsh et al., (2014) so that we could extend their previous research. Walsh and colleagues created happy, sad, and neutral facial expressions from photographs of 3 males and 3 female undergraduate students. The emotions modeled for each expression were not genuinely felt or induced. Then for each of the facial expressions, an average face composite was created by averaging the positions of point-landmarks placed across each of the faces. The composite faces were made using the PsychoMorph face morphing software (Tiddeman, et al., 2001; Tiddeman, et al., 2005). The software identified 189 standard face landmarks on each face, and the position and color of each landmark point were averaged across all images to create an average image (see a *Basic Guide to Psychomorph,* by Sutherland, 2015). An average composite was made for both happiness and sadness separately as well as for a neutral expression to be used in the following step, creating the exaggerated continuum. Happiness and sadness expressions were chosen as they are among the first category of expressions that children begin to understand and label properly (see Widen, 2013 for review).

Next, images of exaggerated facial expressions were created from these composites, resulting in a continuum of 5 images each for the happy expression and the sad expression. Beginning with the happy or sad composite image (the 100% facial expression) exaggerated faces were created by extrapolating the features from the physical difference between the emotional composite and the neutral composite, creating the 150%, 200%, 250%, and 300% expression images. For example, to create the 200% image, the distance between each pair of corresponding points on the two images was doubled. The continuum of exaggerated images was created using the transform function in PsychoMorph. With this function, the physical differences between the happy and the neutral composites and the sad and the neutral composites are computed (Sutherland, 2015). The outline of the neutral face is maintained, while the physical differences between the neutral composite and the expression composite are transformed to create the exaggerated continuum. The transformations were created using four incremented steps that were set via PsychoMorph to create 4 photos beyond the 100% composite expression that increase in exaggeration in 50 % increments, creating the different levels of exaggerated faces (see Calder et al. 2000). Finally, images were cropped to 950 by 450 pixels. The final set consisted of 10 greyscale images, 5 happy and 5 sad, portraying 100%, 150%, 200%, 250%, and 300% exaggeration (see Figure 1).

**Figure 1.**

*100%, 150%, 200%, 250%, 300% exaggerated face continuums for happy and sad faces used as visual stimuli throughout Experiment 1.*

***Apparatus***

The experiment was created and presented with E-Prime 2.0 software on an Asus laptop computer with a 13-inch screen running a Windows 7 operating system. Participants were seated such that their eyes were approximately 60 centimeters away from the screen.

***Measures***

**Wechsler Intelligence Scale for Children-Fourth Edition.** The WISC (Wechsler, 2003) is one of the most often used comprehensive tests of intelligence in children (Gresham & Witt, 1997). The test consists of 15 subtests, 10 of which are used in calculating FSIQ, and the 5 are used as supplementary subtests. The current study used FSIQ as a standardized measure of intelligence and typical development, utilizing only the 10 tests necessary for this calculation. These tests consist of evaluating separate domains of intelligence: Verbal Comprehension (VC), Perceptual Reasoning (PR), Working Memory (WM), and Processing Speed (PS). The core tests are split into subtests. The subtests for VC are Vocabulary, Similarities, and Comprehension. The subtests for PR are Block Design, Picture Concepts, and Matrix Reasoning. The subtests for WM are Digit Span and Letter-Number Sequencing, and the core subtests for PR are Coding and Symbol Search. This allows for an evaluation of a score on each domain or using all domains to calculate a FSIQ. An average FSIQ is considered 90-109, a high average is considered 110-119, a low average 80-90, and a very low average 70-79. The very low average was used as an exclusion criterion for Experiment 1, indicating that the child could potentially not be typically developing and should be excluded from the data analysis.

**Tolerance for Exaggeration.** Tolerance for exaggeration was the dependant measure for the Emotions and the Realism task. In experiment 1 tolerance for exaggeration is operationalized as the proportion of trials in which children select the more exaggerated face as a realistic representation of an emotion. A higher proportion of exaggerated faces selected indicates more tolerance for exaggeration.

**Procedure**

Following the methods described by Walsh et al., (2014) each participant completed the following three computer-based tasks in the same order: The Emotions task (the experimental task), and two control tasks: The Realism Task and the Discrimination Task. Instructions were designed so that children as young as 6 would be able to understand what was expected of them during the trial. Participants were told, "We are developing a computer program that is supposed to create images of people's faces; the faces you are seeing aren't real faces today and were created for this computer game. Sometimes the computer program messes up and the faces don't quite look right. We need your help to make the computer program better so it can create pictures that look more like real people". The function of these instructions was to clarify that the faces being viewed were not of real people and that some may look unusual due to the exaggerations. They were instructed that though these faces may sometimes look unusual they were here to help us improve the computer program by selecting the more realistic representation of each expression.

***Emotions Task***

In each trial, two face images were presented side-by-side. The pair of images differed in the level of exaggeration but portrayed the same expression. Participants were asked, "Which one looks like a REAL person looks if they feel happy/sad?" and instructed to respond via keypress. Each pair of images remained on the screen until the participants made a selection. Participants needed to press the space bar to advance to the next trial.

Participants completed practice trials and test trials, blocked by expression. The order of the expression block presented was counterbalanced across participants. In each block, participants saw all possible pairings of exaggeration levels twice. In total there were 20 experimental trials in each expression block, presented in a randomized order, preceded by 4 practice trials. The practice trials were the same as the test trials in that the participant had to select one of two side-by-side face images of the same expression and asked the same question. The practice trials consisted of stimuli that were comprised of the same models that were viewed in the experimental trials. The participants were given feedback after each practice trial from the computer display to indicate whether they were right or wrong in selecting the least exaggerated, more realistic looking expression. Participants had to get 75% correct on the practice trials, with a maximum of 3 attempts to be included in analyses. All participants did.

***Realism Task***

The Realism task was a control task designed to probe the extent to which emotion perception uniquely contributed to image selection independent of the realism of the face. The task was identical to the Emotions task, except for the question posed to the participant. During the Realism task participants were asked, "Which face is the most realistic?". The practice trials were the same, but participants saw two neutral faces displayed with a distorted facial feature (e.g., rotated eyes, one eye raised above another). Participants only advanced to the experimental trials if they obtained at least 75% accuracy in no more than three attempts on the practice trials. All participants did.

***Discrimination Task***

The Discrimination task was designed to test whether participants could discriminate between the various levels of exaggeration used in the previous tasks. Participants completed 2 expression-blocked sets of trials, in the same order as their previous tasks. Each block consisted of 4 practice trials and 20 test trials consisting of three face images arranged in a triangle with one face near the top of the screen and two below near either the left or right corner of the screen. The three faces portrayed the same expression, and two were of the same exaggeration level. The target face always differed in the level of exaggeration. Participants were asked, "Which one of the faces differs from the others?". The location of the target image (the face differing in exaggeration) was randomly selected for each trial, with each exaggeration level paired with each of the other exaggeration levels twice, once as the target face and once as the distractor face. Participants selected the target face via keypress and pressed the spacebar to advance to the next trial.

These three tasks took approximately 30 minutes and were followed by the WISC-IV (Wechsler, 2003), ($M$=102.08, $SD$=14.54). The entire session lasted approximately 1.5 to 2 hours.

**Results**

Paired sample *t*-tests were conducted to compare the proportion of exaggerated faces selected for happy and sad facial expressions in the Emotions and the Realism tasks. There was not a significant difference between responses to happy or sad faces at the Emotions task, ($t$ (61) =1.05, $p$=0.30, Cohen's $d$ = -0.10) or at the Realism task, ($t$ (61) =0.30, $p$=0.77, Cohen's $d$ = 0.04) (see Table 1). The expressions were therefore collapsed for the following analyses. In the analyses that follow, the dependent variable was the proportion of trials in which the participant chose the more exaggerated image.

**Table 1.**

*Means and standard deviations for Happy and Sad responses across all ages on the Emotions and Realism tasks.*

| | Emotions Task | | Realism Task | |
|---|---|---|---|---|
| | *Mean* | *SD* | *Mean* | *SD* |
| Happy Trials | .31 | .29 | .10 | .18 |
| Sad Trials | .34 | .30 | .09 | .14 |

**Discrimination Task**

All sixty-two participants obtained over 70% accuracy (*M* = 87.20, *SD* = 10.16) and were included in the analyses. Using a Pearson correlation, there was a significant, positive correlation between age and accuracy in discriminating levels of exaggeration on the Discrimination task ($r$ (62) = 0.48, $p$ =<0.001); as children aged, they were more accurate at the task (see Table 2).

**Tolerance for Exaggeration in the Emotions and Realism Task as a Function of Age**

For the Emotions Task, using a Pearson correlation there was a significant, negative correlation between age and tolerance for exaggeration ($r$ (62) = -0.51, $p$ =<0.001); younger participants chose the more exaggerated face more often than the older participants. (See Figure 2a)[2].

For the Realism Task, using a Pearson correlation there was a smaller negative correlation between age and tolerance for exaggeration, which was statistically significant ($r$ (62) = -0.42, $p$ =0.001); younger participants chose the more exaggerated face more often than the older participants. (See Figure 2b).

A paired samples t-test was computed to determine whether the selection of more exaggerated faces differed between the Emotions and the Realism tasks. The Emotions task and the Realism task significantly differed from each other

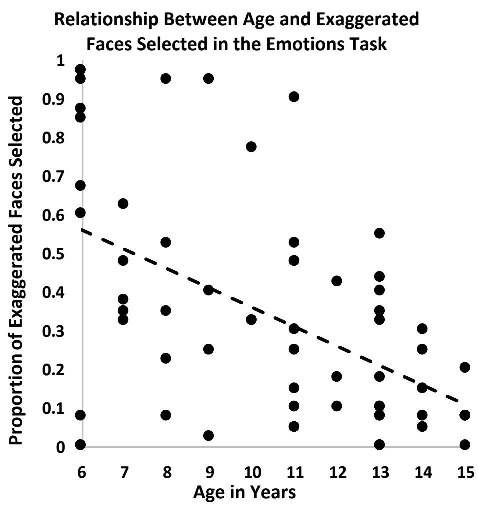
[2] Due to possible outliers in the data analyses (as visualized via box and whisker plots) analyses were also computed using a more robust test of the correlations between age and tolerance for exaggeration with percentage bend correlations (Wilcox, 2012) via the R package *WRS2* and function *pbcor*. A similar pattern of results emerged in the Emotions ($r$ (62) = -0.48, $p$ =<.001) and Realism tasks ($r$ (62) = -0.33, $p$ =0.02).

($t(61)=7.67$, $p$=<0.001, Cohen's $d = 1.17$), with a greater proportion of exaggerated faces selected for the Emotions task ($M$=0.08, $SD$=0.30) than the Realism task ($M$=3.54, $SD$=0.13) (See Table 2 for all means and standard deviations).

Cronbach's alpha was calculated to determine how inter-related each of the tasks was with each other. The Cronbach's alpha for the Emotions, Realism, and Discrimination task was very low ($\alpha = 0.08$) for all three items. In examining only, the Emotions and the Realism tasks, which share identical methods except for the instructions, the Cronbach's alpha was also low for these two items ($\alpha = 0.49$). This suggests that each of the tasks in Experiment 1 is not very inter-related and is probing separate visual-perceptual tasks.

**Figure 2.**

*Relationship between Proportion of Exaggerated Faces Chosen and Age for the Emotions and Realism task.*



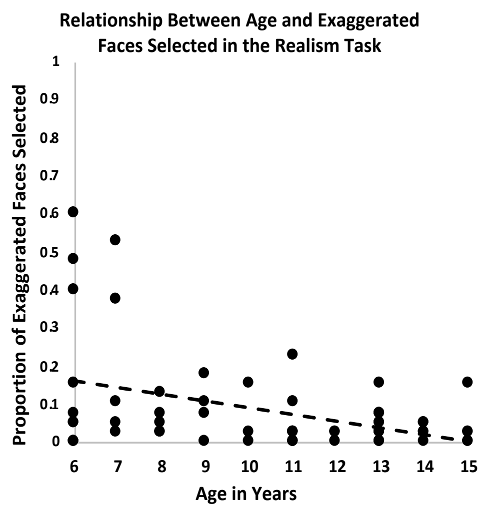




**Figure 2a.** **Figure 2b.**

**Note. 2a.** The relationship between age and the proportion of trials in which the more exaggerated face was chosen as the most realistic representation for happiness and sadness on the Emotions task. **2b**. The relationship between age and the proportion of trials in which the more exaggerated face was chosen as the most realistic representation for happiness and sadness on the Realism task.

**Table 2.**

*Means and standard deviations for each age in the Emotions Task, Realism Task, Discrimination Task, and FSIQ*

*Emotions task*

| Age | *N* | Emotions Task *Mean* | Emotions Task *SD* | Realism Task *Mean* | Realism Task *SD* | Discrimination Task *Mean* | Discrimination Task *SD* | FSIQ *Mean* | FSIQ *SD* |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 10 | 0.60 | 0.41 | 0.18 | 0.23 | 0.80 | 0.08 | 108.50 | 14.05 |
| 7 | 5 | 0.42 | 0.14 | 0.14 | 0.25 | 0.83 | 0.13 | 111.75 | 6.14 |
| 8 | 5 | 0.43 | 0.34 | 0.06 | 0.04 | 0.82 | 0.08 | 112.40 | 9.10 |
| 9 | 4 | 0.41 | 0.39 | 0.09 | 0.07 | 0.90 | 0.11 | 99.50 | 15.80 |
| 10 | 3 | 0.48 | 0.26 | 0.06 | 0.08 | 0.75 | 0.18 | 101.67 | 3.06 |
| 11 | 10 | 0.33 | 0.27 | 0.04 | 0.07 | 0.88 | 0.12 | 97.60 | 17.29 |
| 12 | 3 | 0.23 | 0.17 | 0.02 | 0.01 | 0.94 | 0.05 | 105.67 | 11.59 |
| 13 | 12 | 0.22 | 0.19 | 0.05 | 0.04 | 0.89 | 0.09 | 92.25 | 16.78 |
| 14 | 5 | 0.17 | 0.11 | 0.03 | 0.02 | 0.94 | 0.09 | 103.20 | 15.16 |
| 15 | 5 | 0.09 | 0.07 | 0.04 | 0.06 | 20.78 | 44.29 | 103.60 | 7.50 |

The primary prediction of this experiment was that the proportion of exaggerated images chosen would decline with age, even when performance on the Realism Task was accounted for. A multiple linear regression was conducted to predict proportion of exaggerated faces selected in the Emotions task from proportion of exaggerated faces selected in the Realism task, FSIQ scores, gender, and age. Regression coefficients are shown in Table 3. FSIQ and gender were not significant predictors of tolerance for exaggeration. After accounting for the influence of those variables, tolerance for exaggeration on the Realism task was a significant predictor of tolerance for exaggeration on the Emotion task ($F$ (4,57) = 17.11, $p < 0.001$), with an $\Delta R^2$ of .21. Critically, even after the variance contributed by all three of these variables was accounted for, age was still a significant predictor of tolerance for exaggeration on the Emotion task ($F$ (4,57) = 7.20, $p$ = <.01), with a $\Delta R^2$ of .08.

**Table 3.**

*Summary of Multiple Regression Analyses for Variables Predicting Selection of Exaggerated Faces in the Emotions Task (N = 62).*

| Step | Variable | *b* | *SE(b)* | *β* | $\Delta R^2$ | *F* for $\Delta R^2$ | *p* |
|---|---|---|---|---|---|---|---|
| 1 | FSIQ | 0.005 | .003 | .267 | .085 | 2.74 | .073 |
| | Gender | -.076 | .075 | -.126 | | | |
| 2 | FSIQ | .006 | .25 | .298 | .21 | 17.11*** | <.001 |
| | Gender | -.070 | .002 | -.117 | | | |
| | Realism | 1.043 | .067 | .458 | | | |
| | Exaggeration | | | | | | |
| 3 | FSIQ | .004 | .002 | .201 | .08 | 7.20** | .013 |
| | Gender | -.047 | .064 | -.078 | | | |
| | Realism | .719 | .269 | .314 | | | |
| | Exaggeration | | | | | | |
| | Age | 0.000 | .000 | -.330 | | | |

*$p<.05$, **$p<.01$, ***$p<.0001$

**Note.** Column *b* represents unstandardized beta coefficients and *β* represents standardized beta coefficients.  Full-scale FSIQ was calculated based on each participant's WISC-IV score on the five primary subtests.

## Discussion

Experiment 1 was designed to test the relationship between age and the tolerance for exaggeration of happy and sad expressions. The proportion of exaggerated faces selected did not differ across happiness and sadness trials. Collapsing across emotion, a significant negative relationship was found between age and tolerance for expression exaggeration in children between 6 and 15 years old. This relationship was observed even when tolerance for exaggeration on the emotion-irrelevant control task was accounted for. These results suggest that across 6 to 15 years of age children are developing their adult-like template-matching strategy.

## Experiment 2: The development of template-matching for the basic emotions

Experiment 2 extends the results of Experiment 1 by testing the relationship between age and tolerance for exaggeration across each of the basic emotions, as happiness and sadness are of the first social categories children learn (Widen, 2013) and happiness is the easiest to recognize basic emotion in children (Rodger, Lao, Caldara, 2018). We modified Experiment 2 to focus on the questions of interest: a) does tolerance for exaggeration change with age, b) is this relationship consistent across each of the basic emotions, and c) does this differ between the Emotions and Realism task. Experiment 2 does not include the Discrimination task nor an examination of FSIQ relationship. Experiment 2 examined the same developmental age span as Experiment 1: 6-15 years of age.

New stimuli were created for Experiment 2 to include each of the 6 basic emotions: happiness, sadness, anger, fear, surprise, and disgust with composites based on the same models. Following the same methodology as Experiment 1 an exaggeration continuum of 5 faces was created. All children completed the Emotions and Realism tasks for each of the basic emotions. Tolerance for exaggeration on the Emotions tasks and the Realism tasks was explored. It was hypothesized that age would be negatively related to tolerance for exaggeration on the Emotions task for each of the basic emotions, as in Experiment 1

## Methods

### Participants

Seventy children participated; informed consent was obtained from parents on the behalf of their child. Verbal assent was also obtained from all participants. The sample size for Experiment 2 was similar to Experiment 1. A sensitivity power analysis revealed that a sample of $N = 70$ had 80% power to detect a relationship between age and tolerance for exaggerations of $d = .29$ or greater, encompassing the ability to detect effect sizes as reported by Gao and Maurer (2010) for all basic emotions ($d$= .6- 1.2). Four children were excluded due to either choosing to stop the experiment or a computer error disrupting the data collection. The 4 excluded participants were 2 six-year-old males and 2 seven-year-old males. Sixty-six children ranging from 6 to 15 years old ($M = 9.41$, $SD = 2.36$) were included in the analyses, 26 of which were males. The sample comprised of 10 six-year-olds, 7 seven-year-olds, 8 eight-year-olds, 7-nine-year-olds, 13 ten-year-olds, 7 eleven-year-olds, 8 twelve-year-olds, 3 thirteen-year-olds, 2 fourteen-year-olds, and 1 fifteen-year-old. Fifty of the children were Caucasian, 10 were of mixed race, with one race being Caucasian, 4 were Indian, and 2 parents chose to leave their child's race blank.

Participants were recruited from the same database of children used in Experiment 1. Ethics was obtained from McMaster's research ethics board. Participants received an honorarium of $10 for participation in the study.

**Materials**

A new exaggerated expressions stimuli set was created for Experiment 2 to portray each of the basic emotions (happy, sad, anger, fear, surprise, disgust) from the same models. Though there is evidence of differences in perceiving genuine compared to modeled emotions (Dawel, Wright, Irons, Dumbleton, Palermo, O'Kearney, & McKone, 2017), we used faces from the NimStim database, which are modeled. The NimStim set of facial expressions was chosen because it is a validated stimulus set accurately identified by more than 80% of participants (Tottenham et al., 2009), and because all models produce each of the emotions of interest as well as a neutral expression which was necessary for stimuli formation. Two male and 2 female Caucasian models were selected to construct composite stimuli. The surprise and fear composites consisted of NimStim stimuli in which the model's mouth were open and all other composites were constructed using model stimuli where the mouth was closed. Composite stimuli were constructed using the WebMorph, a web-based version of the

PsychoMorph software package (DeBruine and Tiddeman, 2017). Composites were constructed by auto-delineating and identifying 189 facial landmarks on all of the images. After all images were auto delineated, the average function was applied to average the faces based on the shape and color information of the photographs for each expression. Seven composites were created, one neutral, and one for each of the 6 basic emotions by averaging each of these expressions across the 2 male and 2 female models.

Next, the composites were used to create a continuum of exaggerated faces like Experiment 1, with 5 increasingly exaggerated faces for each of the basic emotions via the transform function through WebMorph. Following similar methodology as Walsh et al. (2014) from each composite, we created a continuum of varying intensity levels. These images were created by using the transform function to calculate the physical difference between the neutral composite and each of the basic emotions separately beyond the 100% expression. Four incremented steps were set via WebMorph to transform and create 4 additional photos beyond the 100% expression that increase in exaggeration. Finally, each of the 30 images were edited via GIMP a free open-source graphics editor (The GIMP Development Team, 2019) to all be made greyscale, oval-shaped, and 311 by 454 dimension. The final set consisted of 30 greyscale images, 5 for each of the 6 basic emotions, portraying 100%, 150%, 200%, 250%, and 300% exaggeration (see Figure 3).

**Figure 3.**

*Stimuli used in Experiment 2.*

**Notes.** 100%, 150%, 200%, 250%, 300% (left to right) exaggerated face continuums for angry, disgust, fear, happy, sad, and surprise (top to bottom).

### *Apparatus*

The apparatus was identical to Experiment 1**.**

## Procedure

The main question in Experiment 2 was to examine whether the same relationship between tolerance for exaggeration and age occurs for each of the basic emotions. As examining 4 additional emotions in Experiment 2 would lead to a significantly longer experiment the Discrimination task was not included in the procedure, so each participant completed: The Emotions task (the experimental task), and the Realism Task (the control task) in the same order.

As there were six basic emotions each participant completed the experiment in one of the 6 counterbalanced orders. The emotion order participants viewed was consisted between the Emotions task and the Realism task. Instructions were identical to Experiment 1.

### *Emotions Task*

Participants completed an Emotions task for each of the basic emotions in 6 separate blocks. They completed practice trials first and then test trials, blocked by expression. The block order was counterbalanced across participants. At the beginning of the first Emotions task set participants were instructed that they would be viewing 2 faces on the screen one on the left and one on the right. They were verbally told to "pick the face that looked like how a real person looks when they are feeling happy/sad/angry/afraid/disgust/surprise" depending on which emotion block was presented first. Selections were made via keypress. Each pair of images remained on the screen until the participants selected, and participants needed to press the space bar to advance to the next trial.

In each test block, participants saw all possible pairings of exaggeration levels twice. In total there were 20 experimental trials in each expression test block, presented in a randomized order, preceded by 3 practice trials. The practice trials were the same as the test trials, except that participants were given feedback after each practice trial. Once an expression block had completed the experimenter then repeated the instructions stating “now you will be selecting the face that looks most like how a real person looks when they are feeling happy/sad/angry/afraid/disgust/surprise” depending on which block of emotion was next. Participants were reminded each time they started a new block that it was beginning with the practice trials and then instructed when the practice trials were completed.

***Realism Task***

As in Experiment 1, the Realism task was identical to the Emotions task except for the instructions and followed the same emotion block order. Participants were reminded before every new block that it would begin with 1 practice trial. After the Realism task was completed, participants were debriefed with their parents. The entire experiment took 30-45 minutes.

## Results

### The Emotions Task

A one-way ANOVA was computed to determine whether the selections of the more exaggerated faces differ based on the emotion type for Emotions tasks. The assumption of homogeneity was not met for the Emotions task as indicated by Levene's Test of Homogeneity of Variances, ($F(3, 39) = 3.88$, $p = 0.002$). Since the assumption of homogeneity of variance was not met for this data, we used the obtained Welch's adjusted $F$ ratio. At least one of the emotions differed based on the number of exaggerated faces selected during the Emotions task ($F(5, 181.74) = 4.50$, $p = 0.001$, $\eta p^2$=0.05) (See Table 4).

**Table 4.**

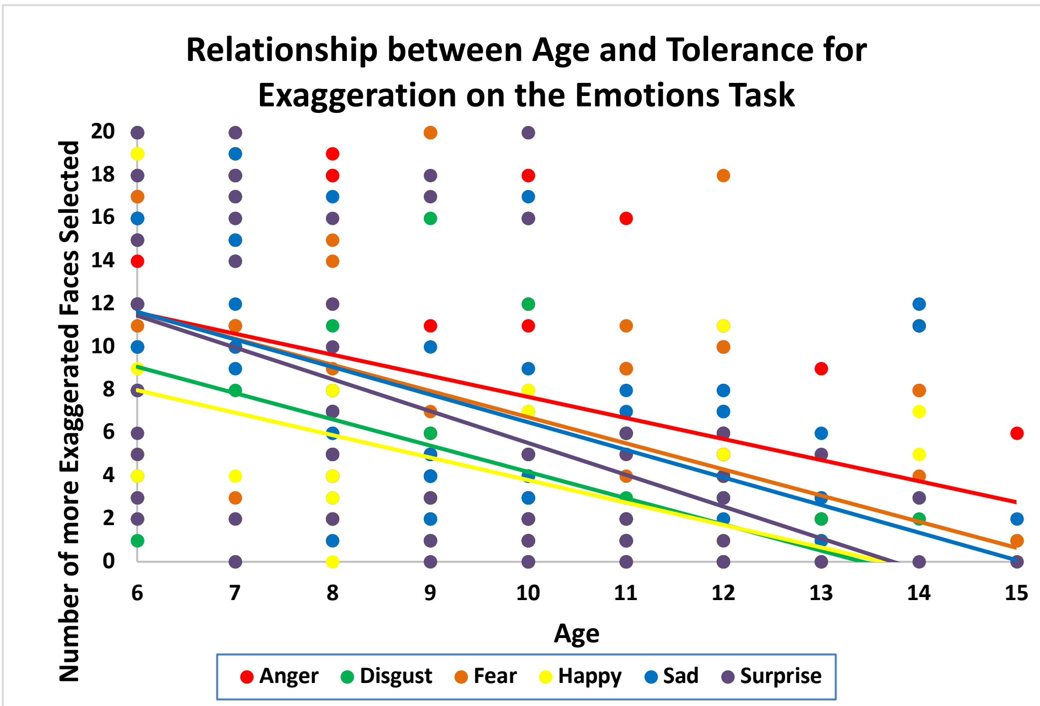
*Means and standard deviations for the number of trials in which the more exaggerated face was selected on the Emotions task.*

| | Anger | | Disgust | | Fear | | Happy | | Sad | | Surprise | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| 6 | 12.30 | 6.58 | 9.20 | 7.22 | 11.30 | 5.42 | 8.90 | 6.98 | 13.80 | 4.76 | 10.90 | 7.02 |
| 7 | 13.57 | 6.40 | 11.00 | 5.97 | 14.57 | 5.80 | 12.14 | 7.03 | 14.29 | 3.99 | 12.43 | 8.04 |
| 8 | 8.00 | 8.57 | 5.38 | 3.29 | 8.75 | 4.65 | 3.00 | 2.62 | 6.75 | 4.56 | 7.75 | 4.59 |
| 9 | 7.71 | 5.99 | 4.71 | 5.25 | 6.00 | 6.48 | 1.57 | 1.13 | 4.29 | 2.87 | 6.14 | 7.84 |
| 10 | 6.54 | 6.24 | 3.15 | 3.44 | 4.62 | 5.30 | 2.38 | 2.63 | 4.15 | 4.47 | 6.23 | 7.64 |
| 11 | 4.86 | 5.96 | 1.57 | 0.98 | 5.00 | 4.16 | 1.57 | 2.07 | 3.71 | 3.15 | 2.14 | 2.41 |
| 12 | 6.63 | 3.62 | 2.38 | 2.07 | 6.25 | 5.73 | 3.38 | 3.62 | 5.25 | 3.11 | 2.25 | 2.31 |
| 13 | 4.00 | 4.36 | 1.33 | 0.58 | 2.33 | 1.15 | 0.67 | 0.58 | 3.33 | 2.52 | 1.67 | 2.89 |
| 14 | 9.50 | 2.12 | 2.50 | 0.71 | 6.00 | 2.83 | 6.00 | 1.41 | 11.50 | 0.71 | 1.50 | 2.12 |
| 15 | 6.00 | - | 1.00 | - | 1.00 | - | 0.00 | - | 2.00 | - | 0.00 | - |

In comparing how each of the basic emotions differed based on their relationship between age and tolerance for exaggeration correlation comparisons were made using confidence intervals (Zou, 2007) and computed via the R package "*cocor* - comparing correlations" (Diedenhofen, & Musch, 2015). The only emotions that significantly differed from each other based on their relationships between age and tolerance for exaggeration on the Emotions task were Anger and Disgust, 95% CI [0.113, 0.3718] and Anger and Sad, 95% CI [0.0025, 0.3461]. In all other comparisons, the confidence intervals included 0 and the emotions were not significantly different from each other based on their relationship between age and tolerance for exaggeration (See Figure 4).

**Figure 4.**

*The relationship between age and the number of trials in which the more exaggerated face was chosen in the Emotions task for each of the basic emotions.*



Due to the significant difference in responses based on the Emotions task, six separate correlations were computed to examine the relationship between tolerance for exaggeration and age. A Bonferroni correction was applied, resulting in a significance level of $p= 0.008$. There was a weak negative correlation between tolerance for exaggeration and age for the Anger trials ($r = -0.36$, $p=0.003$). There was a moderate negative correlation between tolerance for exaggeration and age for the Disgust trials ($r = -0.55$ $p=<0.001$), Fear trials ($r = -0.46$ $p=<0.001$), Happy trials ($r = -0.45$ $p=<0.001$), Sad trials ($r = -0.53$ $p=<0.001$) and Surprise trials ($r = -0.47$ $p=<0.001$) (See Figure 4).

**The Realism Task**

A one-way ANOVA was computed to determine whether tolerance for exaggeration differed based on the emotion type for Realism tasks. There was no differences in selection of the more exaggerated faces for the Realism task based on emotion type ($F(5, 39) = 1.69$ $p = 0.14$, $\eta p^2=0.02$) (see Table 5). As there were no significant differences between emotion type and the number of exaggerated faces selected on the Realism task all emotions were collapsed to examine the relationship between age and tolerance for exaggeration on the Realism task. There was a moderate significant negative correlation between age and tolerance for exaggeration on the Realism task ($r = -0.43$ $p=<0.001$). See Figure 5 for the relationship between age and tolerance for exaggeration on the Emotions and Realism task with all emotions collapsed.

**Table 5.**

*Means and standard deviations for the number of trials in which the more exaggerated face was selected on the Realism task.*

| | Anger | | Disgust | | Fear | | Happy | | Sad | | Surprise | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| 6 | 6.60 | 5.46 | 9.20 | 7.22 | 11.30 | 5.42 | 8.90 | 6.98 | 13.80 | 4.76 | 10.90 | 7.02 |
| 7 | 6.00 | 6.61 | 7.29 | 8.26 | 7.71 | 5.53 | 5.14 | 6.12 | 8.00 | 6.63 | 12.43 | 8.06 |
| 8 | 5.88 | 5.89 | 4.00 | 2.98 | 4.63 | 3.25 | 2.63 | 1.85 | 7.13 | 5.59 | 3.75 | 4.59 |
| 9 | 2.00 | 1.53 | 2.00 | 4.04 | 2.00 | 1.91 | 1.14 | 0.69 | 1.57 | 1.13 | 2.14 | 2.73 |
| 10 | 3.31 | 3.97 | 1.92 | 1.71 | 1.77 | 1.01 | 1.31 | 1.44 | 4.15 | 4.47 | 6.23 | 7.64 |
| 11 | 2.00 | 2.38 | 1.14 | 1.68 | 1.71 | 1.89 | 0.43 | 0.53 | 2.71 | 2.21 | 1.00 | 1.15 |
| 12 | 3.00 | 2.45 | 1.88 | 2.23 | 2.38 | 2.39 | 2.00 | 2.62 | 1.50 | 1.93 | 2.13 | 1.81 |
| 13 | 1.67 | 2.08 | 0.33 | 0.58 | 1.00 | 0.00 | 0.33 | 0.58 | 1.00 | 1.73 | 2.33 | 0.58 |
| 14 | 1.50 | 2.12 | 1.50 | 2.12 | 2.50 | 0.71 | 0.00 | 0.00 | 1.00 | 1.41 | 2.00 | 0.00 |
| 15 | 0.00 | - | 1.00 | - | 0.00 | - | 0.00 | - | 3.00 | - | 0.00 | - |

**Figure 5.**

*The relationship between age and the number of trials in which the more exaggerated face was chosen in the Emotions and the Realism tasks, all emotions collapsed.*

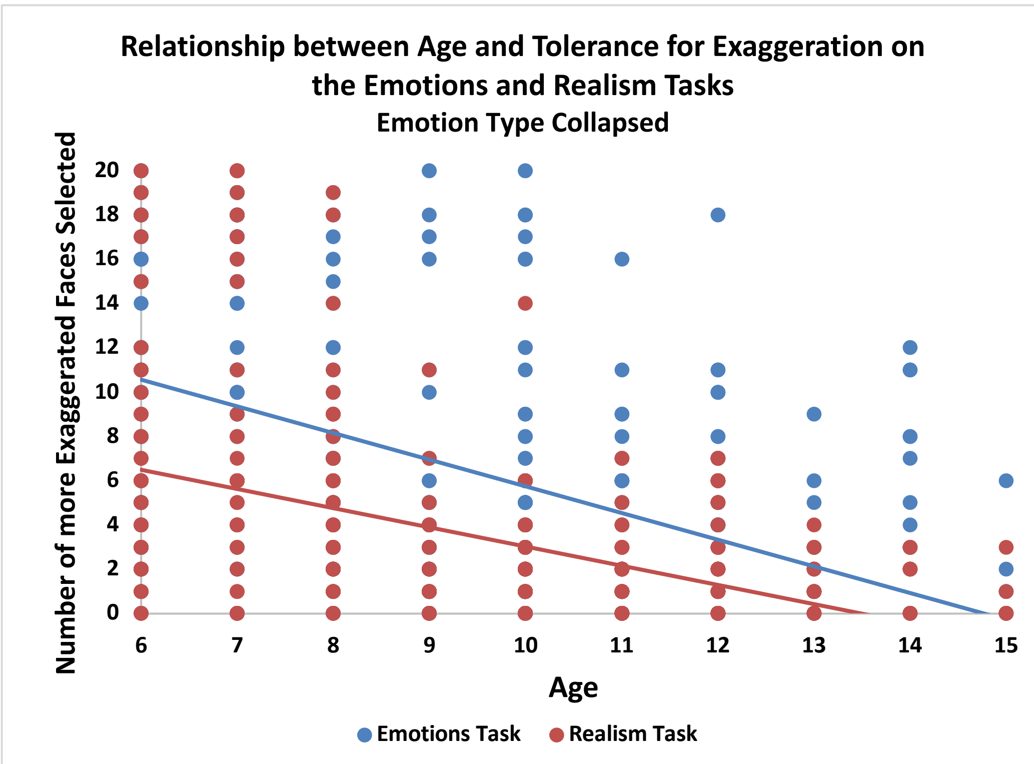


**Table 6.**

*Summary of Multiple Regression Analyses for Variables Predicting Selection of Exaggerated Faces in the Emotions Task for all emotions (N = 66).*

| Step | Variable | *b* | *SE(b)* | *β* | $\Delta R^2$ | *F* for $\Delta R^2$ | *p* |
|---|---|---|---|---|---|---|---|
| 1 | Gender | -0.45 | .63 | -0.36 | -.001 | .511 | .475 |
| 2 | Gender | .02 | .55 | .001 | .24 | 62.29*** | <.001*** |
| | Realism | .66 | .06 | .491 | | | |
| 3 | Gender | .69 | .53 | .06 | .07 | 60.88*** | <.001*** |
| | Realism | 0.48 | .06 | .35 | | | |
| | Age | -.82 | .12 | -.32 | | | |

**p*<.05, ***p*<.01, ****p*<.0001

**Note.** Column *b* represents unstandardized beta coefficients and column *β* represents standardized beta coefficients.

## Discussion

Experiment 2 was designed to examine the relationship between age and the tolerance for exaggeration found in Experiment 1 with each of the 6 basic emotions: happiness, sadness, anger, fear, surprise, and disgust. There were significant negative relationships between age and tolerance for exaggeration for each of the basic emotions, replicating the results from Experiment 1. Between the ages of 6 and 15, children gradually developed their template-matching perception for all basic emotions into adolescence. It is possible that the youngest children may be compensating for a lack of adult-like strategies by utilizing a rule-based strategy, relying more on the position of features of the face and rules for how they should appear for each expression (Rutherford & McIntosh, 2007; Walsh et al., 2014).

The only basic emotions in which tolerance for exaggeration significantly differed for emotion types were anger and disgust and anger and sadness, though each emotion still had a significant negative relationship between age and tolerance for exaggeration. It may be that the developmental span for perceiving realistic negative emotions could differ from other positively valenced emotions (Widen, & Naab 2012), resulting in the differences we observed for anger. Additionally, participants' tolerance for exaggeration differed significantly between the control and the experimental tasks, suggesting that the type of strategy being used in the Emotions task is specific to emotion perception. Though the exaggerated expressions may have been accepted as a realistic representation of that emotion in the younger children, even the youngest of children reject them as a realistic representation of faces in general.

The results from Experiment 2 are consistent with the results from Experiment 1 and suggest that between 6 and 15 years of age children develop an adult-like template-matching strategy for perceiving each of the basic emotions. Before a template-matching strategy emerges, it is possible that younger children compensate by using a different emotion perception strategy, such as a rule-based strategy.

## General Discussion

The current studies were designed to test the relationship between age and the tolerance for exaggeration during expression perception. In Experiment 1 a significant negative relationship was found between age and tolerance for expression exaggeration for happiness and sadness in children between 6 and 15 years old, even when tolerance for exaggeration on the emotion-irrelevant control task was accounted for. In Experiment 2 this relationship was further examined to determine if it was similar for each of the basic emotions: happiness, sadness, anger, fear, surprise, and disgust. The results of Experiment 2 replicate Experiment 1: There was a significant negative correlation between age and tolerance for exaggeration for each of the basic emotions. Both experiments support the idea that as children age, unnaturally exaggerated expressions become less acceptable as realistic depictions of expressions. This is consistent with the idea that between 6 and 15 years of age, children develop a template-matching strategy for perceiving all emotional expressions.

The finding that a template-matching strategy develops through childhood into early adolescence is consistent with previous research on expression perception development. Though children are capable of performing above chance at recognizing the authenticity of expressions, they do not reach adult-like performance until adolescence (Del Giudice & Colle, 2007; Gosselin et al., 2002). The results of Experiment 2 support this notion, replicating Experiment 1 with each of the 6 basic emotions. This suggests that the gradual development of a template-matching strategy from 6 to 15 years of age is robust and consistent across all emotions.

The results from Experiment 2 suggest the gradual development of a template-matching strategy from 6 to 15 years of age on the Emotions task and suggest that the development of the perception of the other 4 basic emotions is similar to happiness and sadness. In Experiment 1 happiness and sadness did not differ based on the proportion of more exaggerated faces selected during the Emotions task. In Experiment 2, tolerance for exaggeration only differed between anger and disgust and between anger and sadness. Tolerance for exaggeration did not differ for any other emotion comparisons, including happiness and sadness.

Though the results from Experiment 2 replicate the pattern of results from Experiment 1, direct comparisons between the two are precluded by the differences in the distortions in the emotion stimuli. Experiment 1 used the stimuli from Walsh et al. (2014), which was created using PsychoMorph face morphing software (Tiddeman, Stirrat, & Perrett, 2001; Tiddeman, Stirrat, & Perret, 2005) and was based on original photographs. The stimuli in Experiment 2 appear less distorted for two reasons: 1) the stimuli were created using WebMorph a web-based and newer version of the PsychoMorph software package (DeBruine and Tiddeman, 2017), and 2) the initial photographs used to create the distorted stimuli were a validated stimuli set, the NimStim in Experiment 2 (Tottenham et al., 2009). Though the stimuli may appear less extreme in Experiment 2 it should be noted that even with these differences, a similar pattern of results emerged.

There was a negative relationship between age and tolerance for exaggeration for all basic emotions, but this relationship was weakest for anger. The slopes of the relationship were significantly different between anger and disgust and between anger and sadness, but no other slopes differed significantly. The differences observed for anger could be due to later development of an understanding of anger compared to other emotions. For example, anger and disgust are commonly mistaken for each other by children when they are asked to label faces (Russell & Widen, 2002; Widen & Russell, 2004; Widen, & Russell 2010). Similar difficulties have been found for anger and other negative valence emotions such as sadness: Children have been found to consider negative emotions such as fear, anger, sadness, and disgust faces to be selected as an "another" interpretation of each other (Widen, & Naab 2012). Though the current study presented the emotions in separate blocks, it is possible that children's relative tolerance of exaggeration when viewing anger expression is related to the later development of an understanding of anger compared to other emotions.

The Realism task served as a control for the Emotions task, testing whether children would choose the more exaggerated face when no longer asked about emotion expression. In Experiment 1 and 2, younger children selected a higher proportion of exaggerated faces than older children. Differing results between the experimental and control tasks suggest a unique role of emotion perception beyond just a perception of realism. The faces viewed in the Emotions and Realism task were identical, so just changing the instructions from making an emotion judgement to a realistic face perception judgement results in less exaggerated faces selected.

Previously Walsh et al. (2014) reported that adults with ASD do not appear to use the same template-based emotion perception strategy as typically developing adults, since they selected more exaggerated faces as a realistic representation of happiness and sadness. Tolerance for unnaturally exaggerated expressions is not consistent with the use of a norm-based template-matching strategy since unnaturally exaggerated expressions would not match the stored representation of that expression. Walsh and colleagues suggested that adults with ASD may instead use a rule-based strategy, focusing more on the position of features in each emotional expression; this strategy would be more tolerant of exaggeration (Rutherford & McIntosh, 2007; Walsh et al., 2014). The tolerance for exaggeration that participants with ASD showed in the Emotions task was diminished in the Realism task. It was hypothesized that if adults with ASD use a rule-based emotion perception strategy on the Emotions task, it must be specific to emotion perception.

In the current study, performance on the Realism task suggested that the children are capable of identifying which of the faces appears less realistic. However, when asked about the emotional displays of the faces in the Emotion task young children showed more tolerance for exaggeration. This contrast demonstrated that children's emotion perception is different from general face processing, and the developmental trajectory revealed in the experimental condition is specific to emotion perception. The results from both Experiments 1 and 2 suggested that the template-matching strategy observed in typically developing adults by Walsh et al. (2014) is a strategy that developed between the ages of 6 and 15 and that the development of the template-matching strategy examined in the Emotions task is specific to emotion perception.

If one were using a rule-based strategy, the more extreme expressions would still follow the "rule" and thus be acceptable. For example, if the rule is "happiness should consist of up-turned corners of the mouth", then the more up-turned they are, the more strongly it fits the rule, making the most extreme stimuli the best answers. It is possible that the younger children in Experiment 1 and 2 used a rule-based strategy, while adolescence were not. Additionally, as children are still refining their "face space" and cognitive representations of faces throughout childhood (Crookes & McKone, 2009; Short et al., 2011), it is possible that template-matching is a specialized strategy for emotion perception, relying on a face template that is still developing. Therefore, while children's face space is developing children may compensate with a rule-based strategy for emotion perception.

Another possible explanation as to why younger children are more likely to select the more exaggerated representation of expressions is that with increased exaggeration the expression may be more apparent to them. Using aftereffects paradigms past research has concluded that children require more distortion to detect abnormality in a face or to adapt to a distorted face (Anzures et al., 2009; Short et al., 2011). Children are also generally less sensitive to facial distortions that may cause a face to look unusual or distinctive (McKone & Boyer, 2006; Mondloch et al., 2004). A lack of sensitivity to unrealistic distortions could explain younger children's selection of more exaggerated expression.

The results from the current studies do not specifically support a constructionist or a naturalist view of emotions. The results of the Emotions task suggest that children develop over time with respect to what they think a realistic representation of each of the basic emotions is. Thus, there may be developmental refinement in learning how a basic emotion appears, supporting a social-constructivist point of view (Ratner, 1989). Though the current studies suggest that the template-matching strategy develops over-time, the experimental paradigm does not directly contrast a constructivist with basic emotion viewpoint.

The current study was not designed to distinguish nature versus nurture, is simply reveals that a perceptual strategy develops into adolescences.

These are not the first studies to test children's sensitivity to expression intensity, though studies have had varying results. Using muted images, less intense than a prototypical display, Gao and Maurer found that sensitivity to happy expression ais adult-like by age 5, (Gao & Maurer, 2009), and sensitivity to surprise and disgust expression is adult-like by age 10 (Gao & Maurer, 2010), but children still confuse low-intensity displays of sadness with fear even at the age of 10 (Gao & Maurer, 2009). Rodger et al. (2015) found that disgust and anger expressions showed a steep improvement in recognition across development, while surprise showed a more gradual improvement. However, Richoz et al. (2018) found that anger had a more gradual development with age. Rodger et al. (2018) found that fear was the most difficult and happiness the easiest to recognize, and the intensity needed to recognize sad, angry, disgust, and surprise expressions decreased with age. Differences in methodology and tasks overall could explain differences between each of the abovementioned studies (Bruce et al., 2000).

Furthermore, Experiment 1 did not differ for the relationship between tolerance for exaggeration and age between happiness and sadness like previous studies (Gao & Maurer, 2009b; Rodger et al., 2015; Rodger,et al., 2018). The relationship between tolerance for exaggeration and age for happiness and sadness had similar development in Experiment 1 and Experiment 2. In Experiment 2 there were some differences across the emotions in terms of the developmental slope. However, emotions only vary significantly between anger and sadness and anger and disgust. Our results indicated differences between sadness and anger, and previously Richoz et al. (2018) found similar gradual trajectories in the perception of both of these negative emotions. These results support our differences observed between anger and disgust in Experiment 2. That said, this is the first study to our knowledge of children's perception of changes in expression intensity using unnaturally exaggerated images. The current studies purposefully chose overly exaggerated faces to contrast rule-based and template-matching emotion perception strategies. This unnatural exaggeration may explain why similar results were not obtained as previous studies examining emotion intensity and perception.

Children's sensitivity to intensity of expressions develops with age (Gao & Maurer, 2009, 2010; Herba et al., 2006) through the age of ten. Children's perception of intensity may be influenced by how adults interact with them, since adults exaggerate expressions and enthusiasm when engaging with infants (Brand et al., 2002). This exaggeration may influence the intensity of their template. In Experiments 1 and 2, younger children are less likely to reject unnaturally exaggerated faces as representations of real emotion expressions. This tolerance of exaggeration is also consistent with the possibility that children's emotion templates are more exaggerated, the results of this study do not rule-out this possibility as we only can determine that children's selections differ from typically developed adults. However, it is unlikely to explain our findings, since our stimuli are not just intense, they are unnaturally exaggerated: children would never see such exaggerated expression in the real world. Nevertheless, evidence from Experiments 1 and 2 suggest that it is not until into adolescence that children begin to use an adult-like template-matching strategy for the Emotions task.

The developmental trajectory found for template-matching expression perception in Experiments 1 and 2 may also be related to the development of configural processing. Children are less sensitive to configural information and more reliant on featural processing than adults when perceiving faces (Del Giudice & Colle, 2007; Gosselin et al., 2002; Thibault et al., 2009). It is likely that configural processing skills are a prerequisite to a template-matching strategy, and these skills have a related developmental timeline. In contrast, a rule-based strategy could be successfully executed while relying only on the appearance of individual features. As the development of configural processing occurs at a similar age as the current evidence for the development of template-matching, children may compensate with another more feature-based strategy while this adult-like perception develops.

## Limitations

A potential limitation of both Experiment 1 and Experiment 2 is the possible influence of the practice trials. Practice trials were included to ensure that participants understood the question and task before starting the data collection block. Since the feedback was given, it is possible that this may have had some training effect on the children. However, all participants across all ages were given the same training, and the developmental relationship between age and tolerance for exaggeration was still observed.

A second limitation of this study is regarding the samples. The sample in experiment 2 does not include as many older children as it does younger children. It is possible that the estimated correlation between age and tolerance for exaggeration would be even stronger if older children were better represented. Future studies should consider broader representation of this age group. The demographic information regarding the sample in experiment 1 does not include the race or ethnicity of the participants. Without this information it is impossible to estimate the generalizability of the results in experiment 1, or to make direct comparisons to the results of experiment 2.

A third limitation was that although IQ was used as an inclusion criterion in Experiment 1, IQ was not measured in Experiment 2 due to the increased session length. ASD symptomology was not screened in either experiment, although the database from which the sample was recruited would have noted if there was an ASD diagnosis in the family, and that participant would have been excluded. This should be considered when interpreting the results since adults with ASD perform differently on the Emotions task than typically developing adults do (Walsh et al., 2014).

Finally, due to the increased length of Experiment 2, the Discrimination task was not included. The Discrimination task was used in Experiment 1 as a control task, ensuring that differences in distortions were perceptible. The stimuli in Experiment 1 and Experiment 2 were constructed from different face models and used morphing technology that had developed in the interim. Therefore, the stimuli distortions may not necessarily appear similarly distorted. Since we created new stimuli for Experiment 2, it is not clear that results from the Discrimination task from Experiment 1 ensure discriminability, so results must be interpreted accordingly.

## Future Directions

Future studies could further examine the development of template-matching strategies by applying eye-tracking technology. Eye-tracking or response classification techniques could directly test which perceptual strategies are used during expression recognition and show exactly where participants of different ages look, and how this may change with development. Eye-tracking could also indicate which features of the face are attended to and whether this differs based on the type of emotion presented, expanding on any differences in the developmental trajectory of template-matching across emotions. Additionally, by examining the areas of the face attended to, it would be possible to further understand whether the development of template-matching is related to configural processing development. The results of the current study only generalize to children's perception of adults' emotion expressions. Future research could examine how children perform on this task while viewing children's faces and test how the template-matching strategy develops with respect to the perception of children's faces.

## Conclusion

Between the ages of 6 and 15, children become less likely to choose an exaggerated facial expression as a realistic representation of an emotional facial expression, which is consistent with the idea that a template-based emotion perception strategy is developing. This result was first observed in Experiment 1 with happiness and sadness. The relationship between age and tolerance for exaggeration was then replicated in Experiment 2 with each of the basic emotions, happiness, sadness, anger, fear, surprise, and disgust. Results of both experiments suggest that across this age range, children may change from using a rule-based expression perception strategy to an adult-like template-matching strategy.

## References

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face Adaptation and Attractiveness Aftereffects in 8-Year-Olds and Adults. *Child Development*, *80*(1), 178–191.

Brand, R. J., Baldwin, D. A., & Ashburn, L. A. (2002). Evidence for 'motionese': Modifications in mothers' infant-directed action. *Developmental Science*, *5*(1), 72–83. https://doi.org/10.1111/1467-7687.00211

Burton, N., Jeffery, L., Calder, A. J., & Rhodes, G. (2015). How is facial expression coded? *Journal of Vision*, *15*(1), 1–1. https://doi.org/10.1167/15.1.1

Burton, N., Jeffery, L., Bonner, J., & Rhodes, G. (2016). The timecourse of expression aftereffects. *Journal of Vision*, *16*(15), 1–1.

Burton, N., Jeffery, L., Skinner, A. L., Benton, C. P., & Rhodes, G. (2013). Nine-year-old children use norm-based coding to visually represent facial expression. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(5), 1261–1269. https://doi.org/10.1037/a0031117

Cook, R., Matei, M., & Johnston, A. (2011). Exploring expression space: Adaptation to orthogonal and anti-expressions. *Journal of Vision*, *11*(4), 2–2. https://doi.org/10.1167/11.4.2

Crookes, K., & McKone, E. (2009). Early maturity of face recognition: No childhood development of holistic processing, novel face encoding, or face-space. *Cognition*, *111*(2), 219–247. https://doi.org/10.1016/j.cognition.2009.02.004

Dawel, A., Palermo, R., O' Kearney, R., & McKone, E. (2015). Children can discriminate the authenticity of happy but not sad or fearful facial expressions, and use an immature intensity-only strategy. *Frontiers in Psychology*, *6*. https://doi.org/10.3389/fpsyg.2015.00462

De Sonneville, L. M. J., Verschoor, C. A., Njiokiktjien, C., Op het Veld, V., Toorenaar, N., & Vranken, M. (2002). Facial Identity and Facial Emotions: Speed, Accuracy, and Processing Strategies in Children and Adults. *Journal of Clinical and Experimental Neuropsychology (Neuropsychology, Development and Cognition: Section A)*, *24*(2), 200–213. https://doi.org/10.1076/jcen.24.2.200.989

Del Giudice, M., & Colle, L. (2007). Differences between children and adults in the recognition of enjoyment smiles. *Developmental Psychology*, *43*(3), 796.

Farajzadeh, N., & Hashemzadeh, M. (2018). Exemplar-based facial expression recognition. *Information Sciences*, *460–461*, 318–330. https://doi.org/10.1016/j.ins.2018.05.057

Gao, X., & Maurer, D. (2009). Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions. *Journal of Experimental Child Psychology*, *102*(4), 503–521.

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

Gosselin, P., Beaupré, M., & Boissonneault, A. (2002). Perception of genuine and masking smiles in children and adults: Sensitivity to traces of anger. *The Journal of Genetic Psychology*, *163*(1), 58–71.

Gresham, F. M., & Witt, J. C. (1997). Utility of intelligence tests for treatment planning, classification, and placement decisions: Recent empirical findings and future directions. *School Psychology Quarterly*, *12*(3), 249–267. https://doi.org/10.1037/h0088961

Herba, C. M., Landau, S., Russell, T., Ecker, C., & Phillips, M. L. (2006). The development of emotion-processing in children: Effects of age, emotion, and intensity. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *47*(11), 1098–1106. https://doi.org/10.1111/j.1469-7610.2006.01652.x

Hess, U., Blairy, S., & Kleck, R. E. (n.d.). The Intensity of Emotional Facial Expressions and Decoding Accuracy. *JOURNAL OF NONVERBAL BEHAVIOR*, 17.

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Jeffery, L., Rhodes, G., McKone, E., Pellicano, E., Crookes, K., & Taylor, E. (2011). Distinguishing norm-based from exemplar-based coding of identity in children: Evidence from face identity aftereffects. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(6), 1824–1840. https://doi.org/10.1037/a0025643

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, A. C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

McKone, E., & Boyer, B. L. (2006). Sensitivity of 4-year-olds to featural and second-order relational changes in face distinctiveness. *Journal of Experimental Child Psychology*, *94*(2), 134–162. https://doi.org/10.1016/j.jecp.2006.01.001

Mondloch, C. J., Dobson, K. S., Parsons, J., & Maurer, D. (2004). Why 8-year-olds cannot tell the difference between Steve Martin and Paul Newman: Factors contributing to the slow development of sensitivity to the spacing of facial features. *Journal of Experimental Child Psychology*, *89*(2), 159–181. https://doi.org/10.1016/j.jecp.2004.07.002

Rhodes, G., Jaquet, E., Jeffery, L., Evangelista, E., Keane, J., & Calder, A. J. (2011). Sex-specific norms code face identity. *Journal of Vision*, *11*(1), 1–1.

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., & Nakayama, K. (2003). Fitting the Mind to the World: Face Adaptation and Attractiveness Aftereffects. *Psychological Science*, *14*(6), 558–566.

Rhodes, G., Jeffery, L., Watson, T. L., Jaquet, E., Winkler, C., & Clifford, C. W. (2004). Orientation-contingent face aftereffects and implications for face-coding mechanisms. *Current Biology*, *14*(23), 2119–2123.

Rhodes, G., & Leopold, D. A. (2011). Adaptive norm-based coding of face identity. *The Oxford Handbook of Face Perception*, 263–286.

Rhodes, G., Pond, S., Jeffery, L., Benton, C. P., Skinner, A. L., & Burton, N. (2017). Aftereffects support opponent coding of expression. *Journal of Experimental Psychology: Human Perception and Performance*, *43*(3), 619–628. https://doi.org/10.1037/xhp0000322

Ross, D. A., Deroche, M., & Palmeri, T. J. (2014). Not just the norm: Exemplar-based models also predict face aftereffects. *Psychonomic Bulletin & Review*, *21*(1), 47–70.

Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus Prototype Matching: Strategies of Perception of Emotional Facial Expressions in the Autism Spectrum. *Journal of Autism and Developmental Disorders*, *37*(2), 187–196. https://doi.org/10.1007/s10803-006-0151-9

Shang, L., & Chan, K. (2008). Temporal Exemplar-Based Bayesian Networks for Facial Expression Recognition. *2008 Seventh International Conference on Machine Learning and Applications*, 16–22. https://doi.org/10.1109/ICMLA.2008.9

Short, L. A., Hatry, A. J., & Mondloch, C. J. (2011). The development of norm-based coding and race-specific face prototypes: An examination of 5-and 8-year-olds' face space. *Journal of Experimental Child Psychology*, *108*(2), 338–357.

Short, L. A., Proietti, V., & Mondloch, C. J. (2015). Representing young and older adult faces: Shared or age-specific prototypes? *Visual Cognition*, *23*(8), 939–956. https://doi.org/10.1080/13506285.2015.1115794

Skinner, A. L., & Benton, C. P. (2010). Anti-Expression Aftereffects Reveal Prototype-Referenced Coding of Facial Expressions. *Psychological Science*, *21*(9), 1248–1253. https://doi.org/10.1177/0956797610380702

Skinner, A. L., & Benton, C. P. (2012). Visual search for expressions and anti-expressions. *Visual Cognition*, *20*(10), 1186–1214.

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

SPRC. (2017). Census Quick Facts: Visible Minorities in Hamilton. *Hamilton's Social Landscape Bulletin*, 1–2.

Sutherland, C. (n.d.). *A basic guide to Psychomorph*. 37.

Thibault, P., Gosselin, P., Brunel, M.-L., & Hess, U. (2009). Children's and adolescents' perception of the authenticity of smiles. *Journal of Experimental Child Psychology*, *102*(3), 360–367. https://doi.org/10.1016/j.jecp.2008.08.005

Walsh, J. A., Vida, M. D., & Rutherford, M. D. (2014). Strategies for Perceiving Facial Expressions in Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *44*(5), 1018–1026. https://doi.org/10.1007/s10803-013-1953-1

Webster, M. A., & Maclin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review*, *6*(4), 647–653. https://doi.org/10.3758/BF03212974

Wechsler, D. (2003). *Wechsler intelligence scale for children-WISC-IV*. Psychological Corporation.

# Chapter 3:

# An explicit religious label impacts visual adaptation to Christian and Muslim faces

Foglia, V., Mueller, A., & Rutherford, M. D. (2021). An explicit religious label impacts visual adaptation to Christian and Muslim faces. *Religion, Brain & Behavior*, 1-20. https://doi.org/10.1080/2153599X.2021.1900901

## Preface

Adult's expertise with faces has been attributed to the use of norm-based coding. Norm-based coding, as proposed by Valentine (1991), suggests that there is a cognitive face norm that adults refer to when viewing faces and that this norm is based on an accumulation of the faces we see throughout our life. As our centered norm is based on experience, it can be manipulated in a laboratory setting. More recently there has been evidence of several categorical face norms that are represented in adult's "face space". The malleability of our face norms has been demonstrated via aftereffects. After viewing distorted faces, other similarly distorted faces appear more attractive or normal than before, as our norm has been temporarily shifted (Rhodes & Tremewan, 1996; Valentine et al., 2004).

More recently the existence of several category-contingent face norms has been explored. Examining the existence of category-contingent face norms has commonly been tested via opposing aftereffects paradigms. This paradigm consists of adapting to two separate categories of faces, distorted in opposite directions (e.g., compressed male faces and expanded female faces) (Bestelmeyer et al., 2008; Little et al., 2005). If after adaptation, attractiveness or normality judgements shift in the direction of adaptation for both of the categories adapted to, separate face norms are considered to exist. Adults have previously been found to have separate face norms for several social categories such as race (Bestelmeyer et al., 2010; Jaquet et al., 2008; Little et al., 2008), sex (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Little et al., 2008; Schweinberger et al., 2010; Watson & Clifford, 2006), emotional expression (Bestelmeyer et al., 2010; Cook et al., 2011; Rhodes et al., 2017; Skinner & Benton, 2010) and in 8-year-old children for race (Short et al., 2011).

Opposing aftereffects require faces to be of socially significant categories and consist of physical differences between the faces (Bestelmeyer et al., 2008; Short & Mondloch, 2010). This chapter controlled for and manipulated these two requirements for opposing aftereffects, examining whether distinct face templates for Christian and Muslim faces are apparent in adults and 8-year-old children. This social category had yet to be explored. In experiment 1 we validated that the Christian and Muslim stimuli categories look perceptually distinct. In experiments 2 and 3 we utilized opposing aftereffects paradigm to determine if adults and 8-year-old children have separate face templates for Christian and Muslim faces.

Experiment 2 utilized a novel methodology, audio cues, to manipulate the religious social relevance of the faces. Opposing aftereffects were only observed for Christian and Muslim faces when they were made socially relevant to the viewer via religious explicit audio cues. Experiment 3 utilized a child-friendly storybook adaptation (Anzures et al., 2009; Short et al., 2011, 2014) exploring if 8-year-old children show evidence of religious opposing aftereffects. Eight-year-old children were told religious information about the characters via the storybook, though aftereffects were not observed.

The implications of this chapter indicated that adults' categorical face templates are highly reliant on the social relevance of the faces we encounter. Religion was found to be another new social category that can be represented in face space, though is reliant on how relevant it is to the viewer. Furthermore, this chapter provided additional evidence that children's social categorical face templates are refining still at 8-years-of-age. Lastly, this chapter provided a valuable new methodology for examining opposing aftereffects, audio cues.

## References

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face Adaptation and Attractiveness Aftereffects in 8-Year-Olds and Adults. *Child Development*, *80*(1), 178–191.

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. https://doi.org/10.1080/13506280802708024

Cook, R., Matei, M., & Johnston, A. (2011). Exploring expression space: Adaptation to orthogonal and anti-expressions. *Journal of Vision*, *11*(4), 2–2. https://doi.org/10.1167/11.4.2

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces.

*Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Rhodes, G., Pond, S., Jeffery, L., Benton, C. P., Skinner, A. L., & Burton, N. (2017). Aftereffects support opponent coding of expression. *Journal of Experimental Psychology: Human Perception and Performance*, *43*(3), 619–628. https://doi.org/10.1037/xhp0000322

Rhodes, G., & Tremewan, T. (1996). Averageness, Exaggeration, and Facial Attractiveness. *Psychological Science*, *7*(2), 105–110. JSTOR.

Schweinberger, S. R., Zäske, R., Walther, C., Golle, J., Kovács, G., & Wiese, H. (2010). Young without plastic surgery: Perceptual adaptation to the age of female and male faces. *Vision Research*, *50*(23), 2570–2576. https://doi.org/10.1016/j.visres.2010.08.017

Short, L. A., Hatry, A. J., & Mondloch, C. J. (2011). The development of norm-based coding and race-specific face prototypes: An examination of 5-and 8-year-olds' face space. *Journal of Experimental Child Psychology*, *108*(2), 338–357.

Short, L. A., Lee, K., Fu, G., & Mondloch, C. J. (2014). Category-specific face prototypes are emerging, but not yet mature, in 5-year-old children.

*Journal of Experimental Child Psychology*, *126*, 161–177. https://doi.org/10.1016/j.jecp.2014.04.004

Short, L. A., & Mondloch, C. J. (2010). The Importance of Social Factors is a Matter of Perception. *Perception*, *39*(11), 1562–1564. https://doi.org/10.1068/p6758

Skinner, A. L., & Benton, C. P. (2010). Anti-Expression Aftereffects Reveal Prototype-Referenced Coding of Facial Expressions. *Psychological Science*, *21*(9), 1248–1253. https://doi.org/10.1177/0956797610380702

Valentine, T. (1991). A Unified Account of the Effects of Distinctiveness, Inversion, and Race in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *43*(2), 161–204. https://doi.org/10.1080/14640749108400966

Valentine, T., Darling, S., & Donnelly, M. (2004). Why are average faces attractive? The effect of view and averageness on the attractiveness of female faces. *Psychonomic Bulletin & Review*, *11*(3), 482–487. https://doi.org/10.3758/BF03196599

Watson, T. L., & Clifford, C. W. G. (2006). Orientation dependence of the orientation-contingent face aftereffect. *Vision Research*, *46*(20), 3422–3429. https://doi.org/10.1016/j.visres.2006.03.026

**Abstract**

Opposing aftereffects can be induced across two sets of face categories. The current literature suggests that in order to create opposing aftereffects, the two categories must 1) be perceptually distinct and 2) represent distinct meaningfully social categories. The current study was designed to test whether religion is one of the types of social categories that can support the formation of opposing aftereffects. Experiment 1 reports the creation and validation of a Christian and Muslim face set, demonstrating that the religious membership of the face images is visually identifiable. In experiment 2 we attempted to create opposing aftereffects by having adult participants fixate on Christian and Muslim faces that were expanded and contracted. Participants either heard religious membership explicit or control audio recordings. Opposing aftereffects were observed only when Christian and Muslim faces were explicitly labeled. In experiment 3, eight-year-olds made were adapted to a similar paradigm, with explicit religious information provided. Opposing aftereffects were not observed. Results of these experiments suggest that for adults, religion might be the kind of meaningful social category required for the formation of opposing aftereffects, but only if religious category membership is made explicit. Eight-year-old children's understanding of religious categories may still be developing.

***Keywords:*** *aftereffects; opposing aftereffects; religion; religious categorization; face templates*

## Introduction

Faces are quickly and automatically categorized by race and sex (Ito & Urland, 2003, 2005; Mouchetant-Rostaing, Giard, Bentin, Aguera, & Pernier, 2000; Tomelleri & Castelli, 2011). Adult face perception relies on norm-based coding (Valentine, 1991), meaning that new faces are compared to a stored representation of an average face template. Face templates are formed based on a lifetime of viewing faces, and they are malleable. When perceiving a new face, the more similar the face is to the stored template, the more attractive and normal it appears (Langlois & Roggman, 1990; Potter & Corneille, 2008; Rhodes & Tremewan, 1996; Valentine et al., 2004).

### Simple Aftereffects

Simple face aftereffects demonstrate the malleability of face templates (Clifford & Rhodes, 2005; Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003; Webster & Maclin, 1999). When adults are repeatedly exposed to faces distorted in a similar manner (e.g. contracted facial features) a shift in the viewers' face template occurs, resulting in other contracted faces appearing more attractive while undistorted faces appear as if they have expanded features (Anzures et al., 2009; Rhodes et al., 2003; Webster & Maclin, 1999). Additionally, following the adaptation of a specific face category (e.g. female) viewing an ambiguous face is perceived as belonging in the opposite category (e.g. male) (Little et al., 2005; Webster et al., 2004). Aftereffects have been observed for gender (Webster, Kaping, Mizokami, & Duhamel, 2004), race (Webster et al., 2004), emotion (Fox

& Barton, 2007; Webster et al., 2004) and identity (Anderson & Wilson, 2005; Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006).

Children as young as 8 years old also show evidence of face aftereffects (Nishimura, Maurer, Jeffery, Pellicano, and Rhodes, 2008). Anzures et al., (2009) found attractiveness aftereffects in 8-year-old children and adults. Furthermore, following similar methods, Short, Hatry and Mondloch (2011) observed simple aftereffects in 5-year-olds. While adults develop aftereffects after viewing faces distorted by 40% and 60%, this level of distortion does not induce aftereffects in children. However, when the distortion strength is increased to 70% or 90% during adaptation, aftereffects are observed in children. These results suggest that children's face templates are still developing (Anzures et al., 2009).

**Opposing Aftereffects**

While simple aftereffects provide evidence for the malleability of prototypical face norms, opposing aftereffects can provide evidence for discrete face templates dedicated to specific social categories. Opposing aftereffects are evident if attractiveness or normality judgements shift simultaneously in opposite directions for each face category after adaptation. In order for opposing aftereffects to form, face categories must be both socially meaningful and physically distinct. Short and Mondloch (2010) explored whether social categorization alone without physical differences could evoke opposing aftereffects. Using a set of face images that were similar on the bases of race, gender and age, the experimenters created artificial "in groups" or "outgroups" based on purported shared personality traits, but opposing aftereffects were not observed, suggesting that without a perceivable physical distinction, face categories do not evoke opposing aftereffects.

Conversely, Bestelmeyer et al. (2008) equated physical dissimilarity while manipulating categorical meaningfulness and testing for gender opposing aftereffects. By manipulating images of female faces, these authors created a set of hyper-female faces such that the physical dissimilarity was equated between a male set and a female set of face images on the one hand, and a female and a hyper-female set of face images on the other. Opposing aftereffects were observed between the male and female stimuli but not between the female and hyper-female stimuli (Bestelmeyer et al., 2008). These results suggest that in order to evoke opposing aftereffects, face sets must a) physically distinct from each other and b) meaningfully social categories in the real world.

Adult observers have shown evidence of opposing aftereffects for race (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008), gender (Jaquet et al., 2008; Little et al., 2005), age, and species (Little et al., 2008). Opposing aftereffects have also been tested in 8-year-old (Short et al., 2011) and 5-year-old children (Short et al., 2014). Short et al. (2011) tested whether 8- and 5-year-old children can develop opposing aftereffects for Caucasian and Chinese faces. Opposing aftereffects were observed in the 8-year-old children, but not in the 5-year-olds. The predominantly Caucasian 5-year-old group adapted only to the distorted Caucasian faces. Short et al. (2014) also tested for opposing aftereffects for race, gender, and age in 5-year-olds but no opposing aftereffects were found. The authors concluded that children's face-space is undifferentiated with respect to these social categories at this age (Short et al., 2011; 2014).

**Religion as a Social Category**

Though opposing aftereffects have been observed in adults and children across race and gender categories (Jaquet et al., 2008; Little et al., 2008; Short et al., 2011, 2014), opposing aftereffects across religious categories have yet to be examined. The open question is whether social categories based on religion can fulfill the two prerequisites for the formation of opposing face aftereffects by being both 1) physically distinct and 2) socially meaningful categories. Religious groups may be represented by one's coalitional psychology with one's own religion as an "in group" and other religious groups as "out groups". Some evidence suggests that individuals' prosocial behaviours are directed towards their own religiously specific in group, and negative attitudes are found toward religious out groups (Johnson, Rowatt, & LaBouff, 2012; LaBouff, Rowatt, Johnson, & Finkle, 2012). Johnson, Rowatt, and LaBouff (2012) found that when Christians are primed with Christian-related words, more negative attitudes towards atheists and Muslims are evident.

Alternatively, religious people in general might be regarded as a social category. Evidence suggests that religious affiliation increases trust, regardless of the specific religious group one belongs to. Christian participants showed increased trust following costly religious signaling regardless of whether the signaler was Christian or Muslim (Hall et al., 2015). Similarly, visible Christian religious signals have been shown to increase trust in the individuals wearing them whether the participant is Christian or non-Christian (McCullough et al., 2016).

Regardless of how positively or negatively religious groups may be viewed, it is plausible that two separate religious face groups may be perceived as separate social categories.  It is unknown whether religion as a social category could evoke opposing aftereffects. If the two religious categories are meaningfully distinct, as is necessary for the formation of opposing aftereffects, opposing aftereffects may occur. However, it is also necessary for the two faces categories to be physically distinct in order to evoke opposing aftereffects. In this series of studies, we first created two sets of religious faces, Christian and Muslim, categorized by their religious identity, and tested whether they are perceptually distinct. We then tested whether explicitly labeling the two categories by religion will create the socially meaningful distinction needed to support opposing aftereffects.

**Current Studies**

Experiment 1 reports the creation and validation of a photoset of Christian and Muslim faces. Since physical differences and a socially meaningful distinction between face categories are required to create opposing aftereffects, we wanted to ensure that the groups of models who self-identified as Christian and Muslim were perceptually distinct.

Christian and Muslim faces were selected as the religious categories of interest for several reasons. These are the two most widely practiced religions in the world (Pew Research Centre, 2017), so they are likely to be recognized as separate religious categories by participants. Prejudice against Muslims is well-documented in North America and Europe (Raiya, Pargament, Mahoney, & Trevino, 2008; Strabac & Listhaug, 2008). There has also been a recent surge of Islamophobia in North America: Muslim individuals are considered a cultural "other" to Western culture (Grosfoguel, 2012; Said & Laade, 1978), with growing intensity in hate crimes and Islamophobic biases in the years immediately after 9/11 (Bail, 2014; Peek, 2011). Recently hostility towards Muslims has become part of political discussion, with the Trump administration's travel restrictions, referred to as a "Muslim ban" (Husain, 2018) introduced in Donald Trump's first days as president of the United States. Thus, Christian and Muslim models were selected due to the likelihood of these face categories being perceived as socially meaningful categories.

The main manipulation in experiment 2 was whether Christian and Muslim faces were identified by religion, using explicit audio recordings. Half of the participants adapted to faces while hearing explicit religious information about the models, and the other half heard non-religious information about the models. If these face sets support the formation of opposing aftereffects in the condition without explicit religious labels, then it is possible that a social categorical distinction was made based on the image alone, similar to opposing race aftereffects. However, if there are opposing aftereffects only when the religious label is explicitly given, it would suggest that the images alone don't support the formation of religious opposing aftereffects.

In experiment 3 we examined whether children form opposing aftereffects for Christian and Muslim faces. Experiments 2 and 3 follow a similar design as Short et al. (2011), in which a social category was first examined for possible aftereffects in adults and then in 8-year-olds. It is not clear whether religion is the type of social category that supports the formation of opposing aftereffects in adults and children, or how this can be affected by explicit religious information. The current studies will be the first test for evidence that adults and 8-year-olds can form opposing aftereffects for social categories defined by religion.

## Experiment 1: Photo Stimuli Validation

Experiment 1 consisted of creating and validating a set of Christian and Muslim face photographs with the intention of using the stimuli in experiments 2 and 3. As different religions are more or less prevalent in different regions of the world, individuals who practice Christianity or Islam may appear physically different. Since physical differences between face categories are required to create opposing aftereffects, we wanted to ensure that the groups of models who self-identified as Christian and Muslim are perceived as distinct. Experiment 1 examines whether the models in these two face sets can be identified as the religious category consistent with the model's self-identification.

### Methods

**Stimuli creation**

Undergraduate students were recruited through emails and social networking groups for McMaster University as models for experiment 1. The recruitment emails asked for Christian and Muslim models and consisted of a set demographic questions about their and their family's religious heritage. All models self-identified as Christian or Muslim. The Christian models consisted of 15 males and 21 females, and the Muslim models 15 males and 14 females (*M* age= 20.21, *SD*= 2.02, *range*: 17-27). Of the Christian models: 31 were born in Canada, 2 in Mexico, and 1 in each England, Germany, and Romania. Of the Muslim models, 14 were born in Canada, 5 were born in Pakistan, 3 in Egypt, 3 in Iran, and 1 in each Afghanistan, Bangladesh, India, and the United States (see table 1 for additional demographic information). All models gave written consent to have their photo taken for research purposes.

Photographs were taken using a Canon Rebel T3, against a white 57.2 x 72.4 cm Bristol board. The camera was approximately 6 feet from the model. All models wore a black salon cape to cover their clothing, were asked to maintain a neutral face and remove any glasses. After models were photographed, they answered a demographics questionnaire about their age, gender, the country they were born in, and their religious heritage. Models self-identified religious heritage determined category membership for the validation study. Models were compensated $5 for their time.

**Table 1.** Number and percentage of times participants misidentified each of the images (*N*=40*)*. Image IDs that start with M are Muslim and C are Christian, when the ID's second letter is F it is a female model and M a male model.

| ID | Religion | Country of Birth | Age | Number of participants to misidentify | Percentage of participants that misidentify |
|---|---|---|---|---|---|
| MF4142 | Muslim | Iran | 21 | 27 | 67.5 |
| CM4214 | Christian | Canada | 20 | 24 | 60 |
| CM4219 | Christian | Canada | 20 | 23 | 57.5 |
| CM4272 | Christian | Canada | 19 | 21 | 52.5 |
| CF4087 | Christian | Mexico | 20 | 19 | 47.5 |
| CF4167 | Christian | Mexico | 20 | 19 | 47.5 |
| MF4247 | Muslim | Canada | 24 | 19 | 47.5 |
| MM4240 | Muslim | Canada | 20 | 18 | 45 |
| CF4173 | Christian | Canada | 20 | 16 | 40 |
| CM4198 | Christian | Canada | 26 | 16 | 40 |
| MM4262 | Muslim | Canada | 18 | 16 | 40 |
| CF4118 | Christian | Canada | 24 | 15 | 37.5 |
| MM4259 | Muslim | Canada | 18 | 14 | 35 |
| MM4267 | Muslim | Canada | 21 | 14 | 35 |
| MF4230 | Muslim | Iran | 19 | 12 | 30 |
| CF4150 | Christian | Romania | 22 | 11 | 27.5 |
| CF4180 | Christian | Canada | 20 | 11 | 27.5 |
| MF4255 | Muslim | Canada | 20 | 11 | 27.5 |
| MF4256 | Muslim | Afghanistan | 19 | 11 | 27.5 |
| MM4270 | Muslim | India | 18 | 11 | 27.5 |
| CM4169 | Christian | Canada | 20 | 10 | 25 |
| MF4228 | Muslim | Canada | 19 | 10 | 25 |
| MM4191 | Muslim | Canada | 20 | 10 | 25 |
| CF4098 | Christian | Canada | 19 | 7 | 17.5 |
| MM4238 | Muslim | Canada | 19 | 7 | 17.5 |
| CF4141 | Christian | Canada | 20 | 6 | 15 |
| MM4206 | Muslim | Pakistan | 21 | 6 | 15 |
| MM4257 | Muslim | Egypt | 18 | 6 | 15 |
| MM4264 | Muslim | Canada | 18 | 6 | 15 |
| CF4115 | Christian | Canada | 20 | 5 | 12.5 |
| CF4156 | Christian | Canada | 20 | 5 | 12.5 |

| | | | | | |
|---|---|---|---|---|---|
| CF4171 | Christian | Canada | 20 | 5 | 12.5 |
| MF4133 | Muslim | Canada | 20 | 5 | 12.5 |
| MM4236 | Muslim | Pakistan | 20 | 5 | 12.5 |
| MM4278 | Muslim | Egypt | 21 | 5 | 12.5 |
| CF4184 | Christian | Canada | 18 | 4 | 10 |
| CF4203 | Christian | Canada | 26 | 4 | 10 |
| CM4224 | Christian | England | 20 | 4 | 10 |
| MF4211 | Muslim | Iran | 21 | 4 | 10 |
| MF4231 | Muslim | Bangladesh | 19 | 4 | 10 |
| CF4126 | Christian | Canada | 23 | 3 | 7.5 |
| CF4175 | Christian | Canada | 17 | 3 | 7.5 |
| CM4164 | Christian | Canada | 21 | 3 | 7.5 |
| CM4186 | Christian | Canada | 20 | 3 | 7.5 |
| CM4188 | Christian | Canada | 26 | 3 | 7.5 |
| MF4208 | Muslim | Canada | 20 | 3 | 7.5 |
| MF4218 | Muslim | Canada | 19 | 3 | 7.5 |
| MF4226 | Muslim | Canada | 19 | 3 | 7.5 |
| MM4266 | Muslim | Egypt | 22 | 3 | 7.5 |
| CM4103 | Christian | Canada | 19 | 2 | 5 |
| MF4196 | Muslim | U.S.A. | 20 | 2 | 5 |
| MM4147 | Muslim | Pakistan | 20 | 2 | 5 |
| MM4234 | Muslim | Pakistan | 19 | 2 | 5 |
| CF4108 | Christian | Canada | 19 | 1 | 2.5 |
| CF4123 | Christian | Germany | 27 | 1 | 2.5 |
| CF4182 | Christian | Canada | 18 | 1 | 2.5 |
| CM4177 | Christian | Canada | 20 | 1 | 2.5 |
| CM4222 | Christian | Canada | 20 | 1 | 2.5 |
| CM4253 | Christian | Canada | 20 | 1 | 2.5 |
| CM4276 | Christian | Canada | 19 | 1 | 2.5 |
| MF4193 | Muslim | Pakistan | 20 | 1 | 2.5 |
| CF4069 | Christian | Canada | 20 | 0 | 0 |
| CF4092 | Christian | Canada | 19 | 0 | 0 |
| CF4111 | Christian | Canada | 19 | 0 | 0 |
| CM4152 | Christian | Canada | 20 | 0 | 0 |

**Photo stimuli validation**

The religious stimuli bank was then validated to confirm that there were observable physical differences between the Christian and Muslim models. Additionally, validating the stimuli confirms that the religion the models self-identified with matches what the participants categorize them as.

Ethics permission for experiment 1, 2 and 3 was obtained by the McMaster University Research Ethics Board. The validation study was conducted online via Gorilla.sc. During the informed consent window participants were informed that this was a stimuli validation study designed to explore whether the models appear as either Christian or Muslim. They were informed that they would be viewing 65 images of Christian or Muslim individuals and that these individuals have self-reported their religion. After consenting to the study participants provided some demographic information about their age, gender, race, country of birth, their own religious heritage, their family's religious heritage, and their frequency of religious practice.

At the beginning of the experimental phase instructions were displayed on the screen informing the participants that the models have self-identified their religion and that they must choose whether they think each face appears Christian or Muslim based on their first immediate choice. Participants pressed a button indicating when they were ready to move onto the experiment. Participants viewed each of the 65 images one at a time in a randomized order. Each image was displayed in the middle of the screen with 2 buttons below to select whether they thought the face appeared Christian or Muslim. Half of the participants viewed the Christian button on the left, the other half on the right. After completing all 65 images participants were debriefed and that study was complete. The entire session took 10-15 minutes.

**Participants**

Forty participants took part in the validation study, 30 females, 9 males, and 1 non-binary (*M* age = 19.46, *SD*= 1.75, *range*: 17-26). The average frequency of religious practice was 2.1 (*SD* =1.35) on a 5-point scale with 5 being the most frequent (see table 2 for additional demographic information).

**Table 2.** Demographics information from participants in experiment 1.

| | Participants (*N*= 40) |
|---|---|
| Race | |
| South Asian | 14 |
| Asian | 13 |
| Caucasian | 9 |
| Black | 2 |
| Mixed-race | 2 |
| Country of birth | |
| Canada | 21 |
| China | 8 |
| Iraq | 2 |
| Romania | 1 |
| Taiwan | 1 |
| United Arab Emirates | 1 |
| United States | 1 |
| Sri Lanka | 1 |
| Pakistan | 1 |
| Jordan | 1 |
| Malaysia | 1 |
| Israel | 1 |
| Religious practice | |
| Atheist or Non-religious | 14 |
| Catholic or Christian | 9 |
| Muslim | 7 |
| Hindu | 4 |
| Sikh | 2 |
| Buddhist | 1 |
| Taoism | 1 |
| Jewish | 1 |
| Mixed-religious | 1 |

## Results

Of the 65 model photos categorized the average correctly identified was 81.18% of models, or 56.78 out of 65 images (*SD* = 5.13). Four of the model images were correctly identified by all participants (See table 1 for details on misidentified images). The maximum correctly identified model images by any participant was 62 and the minimum was 39. Of the 489/2600 misidentified trials, 249 were Christian models misidentified as Muslim, and 240 were Muslim models misidentified as Christian. A single-sample *t*-test was conducted to assess if participants' ability to categorize each model image was better than chance (50%, 2 AFC task). Participants correctly categorized model faces better than chance ($t(39) = 24.99$, $p = <0.001$). Only 4 models were misidentified by half of the participants and were therefore not included in the pre- and post-adaptation phases in either experiment 2 or 3. Additionally any images that were not accurately identified by over half of the participants in experiment were not used in pre- and post- adaptations in experiments 2 and 3.

To test whether country of birth was related to religious identity, a chi-square was computed to determine the association between religious identity of the models (Christian or Muslim) and country of birth (being born in Canada or outside of Canada). There was a significant relationship between religious identity and country of birth, Muslim models were more likely than Christian models to be born outside of Canada ($X^2$ $(1, N = 65) = 10.70, p = .001$). A linear regression was computed to predict the model's frequency of misidentification from their age, country of birth, and religious identity. The regression model was not significant, ($F(3,61) = .407$, $p = .749$) with an $R^2$ of 0.020. Model's age, country of birth, and religious identity were not significant predictors of the frequency they were misidentified.

**Discussion**

The purpose of study 1 was to validate a novel face image set with Christian and Muslim models for use in experiments 2 and 3. We found that the Christian and Muslim models were accurately categorized as members of their self-identified religious group. This result suggests that there were perceptible physical differences between Christian and Muslim faces in this stimulus set, allowing us to proceed with experiments 2 and 3.

**Experiment 2: Religious Opposing Aftereffects in Adults**

Experiment 2 was designed to test whether, for adults, religion is the kind of meaningful social category that can support the formation of opposing aftereffects. In order to manipulate social significance, participants were assigned to either a religious explicit or a control condition. The religious explicit condition included audio recordings that were played during the adaptation phase and that signaled religious category membership through Christian or Muslim names and religious-relevant character descriptions. During the pre- and post-adaptation phases, face images were paired with either a Christian name or a Muslim name presented via audio recordings for the religious explicit condition. The control conditions included audio recordings of religious-neutral character descriptions, and faces were paired with religious-neutral names. If aftereffects were observed without the religious information, this would suggest that a social categorical distinction is made based on the image alone, as is the case for opposing race aftereffects (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008). However, if aftereffects were only observed in the conditions with religious labels, this would suggest that the images alone do not support the formation of opposing religious aftereffects, and that adaptation was influenced by the explicit social information. This is the first attempt at exploring the effect explicit religious labels have on face perception.

## Methods

### Materials and stimuli development

**Photo editing**. There was an inclusion criterion for the photos used as stimuli in in study 2. All of photos were correctly categorized by 81.18% of participants in experiment 1. These photos were then cropped to 1530 pixels by 1837 pixels using PhotoPad Image Editor, maintaining the aspect ratio. Following cropping, all photographs were edited using the spherize function on Adobe Photoshop CS. For experiment 2 each photograph was expanded by 60% and 10% and contracted by 60% and 10% (see Figure 1).

Christian Female –10% Christian Female +10% Christian Female –60% Christian Female +60%

Muslim Male – 10% Muslim Male +10% Muslim Male -60% Muslim Male +60%

*Figure 1*. Stimuli samples of the Christian and Muslim faces used in experiment 2. Pre and post adaptation phases consisted of presenting +/- 10% Christian and Muslim faces. Adaptation consisted of +/- 60% Christian and Muslim faces

**Audio stimuli.** All audio recordings for the religious explicit and control conditions were created via iPhone application Voice Recorder Audio Editor. Recordings used in the pre- and post-adaptation phases included 12 Christian and Muslim names for the religious explicit condition and 12 religious neutral names for the control condition. Four additional sentences were recorded as character descriptions in the adaptation phase. The sentences either indicated the individuals' place where they practiced their faith, their favourite food, what they are studying in school, and what their plans for the summer were.

**Participants**

One hundred and twenty-four McMaster University students participated (19 male). This sample size was determined using a power analysis with average effect sizes from the literature ($k$=4, $f$=0.30, $\beta$=0.8, $\alpha$ =0.05) (interaction effects (Little et al., 2008; Short et al., 2011). Data from one male and one female participant were excluded due to a computer error. The one hundred and twenty-two participants ages analyzed (17 to 41 years old, $M$= 18.81, $SD$=2.88). Participants received course credit for their time. Informed consent was obtained from all participants.

**Procedure**

The paradigm consisted of a pre-adaptation, adaptation, and post-adaptation phase. Participants were assigned to one of four conditions. Conditions differed by the audio recordings presented (religious explicit or control) and the direction of face distortions (Christian expanded, and Muslim contracted, or

Muslim expanded and Christian contracted). Each of the religious explicit and control conditions consisted of one condition where participants were adapted to contracted Christian and expanded Muslim faces and one condition where participants were adapted to expanded Christian and contracted Muslim faces.

Audio recordings played with face stimuli during the adaptation phase. For the religious explicit condition, one of the three-character description sentences mentioned where the character practiced their faith (e.g., "Leah's family is Catholic, and they spend their Sundays at church" or "Hasan's family is Muslim, and they worship at a mosque"). The two other audio recordings indicated the character's favourite food (e.g., "Leah's favourite food is pizza") and what they are studying in school (e.g., "Hasan is in school to become a psychologist"). Control audio recordings used neutral names and consisted of sentences about the stimuli's favourite food, what they are studying in school, and what their plans for the summer are (e.g., "Warren is planning to take a trip to Europe in the summer").

**Pre-adaptation phase.** Participants viewed 12 pairs of faces, 4 times each, in a randomized order. Each pair consisted of the same model, with one face expanded by 10% and the other contracted by 10%. Six of the face pairs were Christian and 6 were Muslim.  For each of the 4 times a pair was presented, half of the time the expanded face was on the left, and the other half the right. An audio recording played along with each face pair presented stating the name of the face. Each pair was presented for 2 seconds, followed by a prompt screen instructing the participants to select via keypress which face they found more attractive. An attractiveness selection was obtained for all 48 pairs of faces.

**Adaptation phase.** Throughout the adaptation phase participants observed distorted faces that were either Christian or Muslim, depending on condition. All participants viewed 3 Christian faces and 3 Muslim faces one at a time, 3 times each. Faces were presented in a randomized order for 7 seconds per face with a 500 millisecond inter-stimulus interval. Each face was paired with a character description via audio recording.

**Post-adaptation phase.** The post-adaptation phase was similar to the pre-adaptation phase, with the addition of 6 top up faces after each attractiveness selection in order to maintain the adaptation gained from the previous phase, were presented. Top-up faces are commonly used to maintain the adaptation from the adaptation phase throughout the post-adaptation trials in which the faces presented are less distorted than those in adaptation. Top-up faces were distorted consistent with the adaptation direction for each condition at -/+ 60%. The top up faces were randomly generated from the same stimuli set used during the adaptation phase. Each top up face was shown for 1 second before the next pair of faces was presented.

**Questionnaires**

Following the three phases, participants completed a demographics questionnaire that asked about their age, gender, country they were born in, ethnicity, family's religious heritage, and religion that they practiced. A religiosity scale was completed, asking participants to rate how often they practice their religion on a scale from 1-5. The religion practiced by the participants was diverse: with 48 Christian/Catholic, 40 non-practicing, 21 Islam, four Hindu, four Jewish, three Sikh, one Jainism, and one mixed.

## Results

### Examining pre-adaptation selections

As change scores are influenced by pre-adaptation selections for attractiveness, we first examined whether there were differences in the pre-adaptation attractiveness selections. A 4 (adaptation condition: religion explicit or control condition) by 2 (religion: Christian or Muslim model) mixed ANOVA was conducted. For the pre-adaptation attractiveness ratings there was a main effect of religion, ($F(1,119)=39.153$, $p= <0.01$), more Muslim contracted faces were selected as most attractive when Muslim face pairs were presented with one expanded and one contracted side by side ($M=16.62$ out of 24 Muslim face pairs) than contracted Christian faces when participants viewed Christian face pairs selected as more attractive ($M=14.59$ out of 24 Christian face pairs). However, there was no main effect of condition ($F(3,119)=0.481$, $p= 0.696$), and no condition by religion interaction ($F(3,119)=1.425$, $p= 0.239$). Since attractiveness selections did not differ across conditions, we continued to use the pre-adaptation scores to calculate the change in attractiveness scores.

### Differences between the religious explicit and control adaptation conditions

In order to examine whether the adaptation conditions influenced attractiveness ratings overall adaptation conditions and whether the religious explicit and control conditions differed, a 4 (all adaptation conditions: 2 religious explicit conditions and 2 control conditions) by 2 (religion: Christian or Muslim face) mixed ANOVA was conducted. Change scores were the dependent variable; all adaptation conditions were the between-subjects factor and religion the within-subjects factor. The dependent measure was the change in the number of contracted faces selected as more attractive from the pre versus the post-adaptation phases as change in attractiveness selections would be reflective of whether adaptation was obtained for both face categories independently. A significant main effect for religion ($F(1, 119)=6.03$, $p= 0.02$, $\eta_p^2 =0.048$) was observed: there was a greater change in number of contracted Christian faces selected as more attractive ($M=1.63$, $SD=4.363$) compared to Muslim faces ($M=0.72$, $SD=4.23$), ($t(122)=2.29$, $p= 0.02$, Cohen's $d = 0.21$). A significant interaction between all adaptation conditions and religion ($F (3, 119) =4.60$, $p= 0.004$, $\eta_p^2=0.10$) was also observed, though the main effect of condition was not ($F(1, 119)=1.61$, $p= 0.19$). This interaction was further examined by exploring the Religious explicit and control conditions separately.

**Religious Explicit Conditions**

A 2 (adaptation condition: adapted to expanded Christian/contracted Muslim or contracted Christian/expanded Muslim faces) by 2 (religion: Christian or Muslim face) mixed ANOVA was conducted for the two religious explicit conditions. The change scores were the dependent variable and adaptation condition was the between subjects' factor and religion the within subjects' factor. A significant main effect for religion was found ($F$(1, 58)=9.63, $p$= 0.003, $\eta_p^2$=0.14): There was greater change for Christian ($M$=1.40, $SD$=2.86) compared to Muslim faces ($M$= -0.18, $SD$=4.12), ($t$(59)=2.86, $p$= 0.006, Cohen's $d$=0.45). A significant interaction was found between adaptation condition and religion ($F$(1, 58)=11.32, $p$= 0.001, $\eta_p^2$=0.16), though no main effect of adaptation condition was found ($F$(1, 58)=0.11, $p$= 0.74).

Aftereffects were assessed through paired $t$-tests for each adaptation condition separately to determine if the change of preference for contracted faces is consistent with the direction of adaptation for the Christian and Muslim faces presented. For the contracted Christian/expanded Muslim adaptation condition significant aftereffects were observed ($t$(29)=4.36, $p$= <0.001, Cohen's $d$= 0.663), with more change in preference when contracted Christian faces were adapted to ($M$=2.43, $SD$=5.74), than when expanded Muslim faces were adapted to ($M$= -0.87, $SD$=4.08), consistent with direction the faces were presented during adaptation. However, there was no difference in change in preference for contracted faces in the expanded Christian/contracted Muslim condition ($t$(29)=-0.20, $p$= 0.85). Thus, opposing aftereffects were significant for the Christian contracted/Muslim expanded condition (see Figure 2).

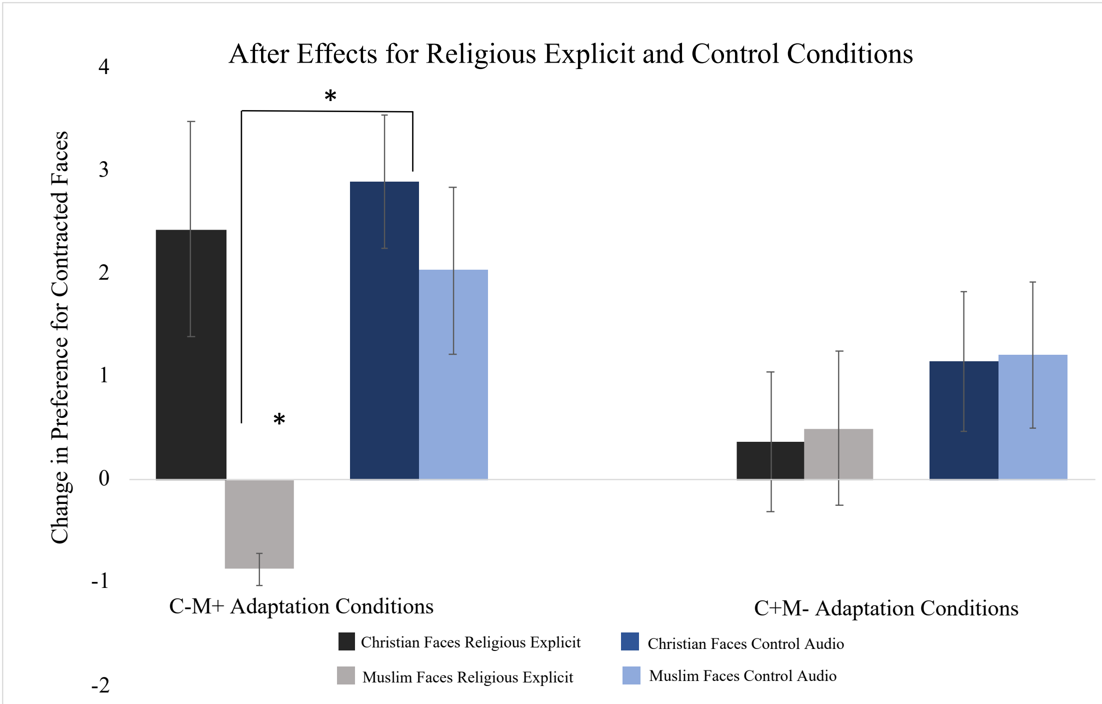



*Figure 2.* Mean change in preference for contracted faces selected from pre to post adaption for all adaptation conditions in experiment 2. Significant aftereffects are observed for the C-M+ (Christian contracted/ Muslim expanded) religious explicit conditions but not the control conditions.

*Note.* C-M+ signifies Christian contracted/Muslim expanded adaptation conditions and C+M- Christian expanded/ Muslim contracted adaptation conditions.

**Control Condition**

A 2 (adaptation condition: adapted to expanded Christian/contracted Muslim or contracted Christian/expanded Muslim) by 2 (religion: Christian or Muslim face) mixed ANOVA was conducted with the two control conditions pooled. The was no main effect of religion ($F(1,61)=0.24$, $p= 0.62$) or adaptation condition ($F(1,61)=2.35$, $p= 0.13$) or interaction between adaptation condition and the religion ($F(1,61)=0.70$, $p= 0.45$). No aftereffects were observed for either control conditions (see Figure 2).

**Adaptation to Categorically Ambiguous Models**

In order to test whether the adaptation in Christian contracted/ Muslim expanded faces in the Religious explicit condition was implanted by the explicit religious labels, adaptation to the two most misidentified Christian and Muslim female faces from Experiment 1 were further explored. We tested whether these two most ambiguous models face show evidence of adaptation using a one-sample *t*-test comparing change scores for both faces to 0. If the change score from pre- to post-adaptation was 0 it would indicate no evidence of adaptation. Change scores were different from 0, ($t(59)=4.45$, $p = <.001$) indicating adaptation for the most ambiguous faces when religious label were present in the direction predicted by the model’s category membership.

Additionally, participants’ change scores to these two faces were examined for opposing aftereffects through directional expectant, one-tailed paired *t*-tests. For the contracted Christian/expanded Muslim adaptation condition, significant aftereffects were observed ($t(29)=2.036$, $p= 0.025$), with more change in perception for Christian faces ($M=.42$, $SD=1.38$), compared to Muslim faces were adapted to ($M= -0.13$, $SD=1.17$), consistent with the direction the faces were presented during adaptation. However, there was no difference in change in preference for contracted faces for the same faces in the control condition when religious labels were not provided ($t(29)=1.07$, $p= 0.15$).

**Effect of Explicit Religious Labels**

Change scores were compared across religious explicit trials and control trials for both the adaptation conditions (contracted Christian/expanded Muslim and expanded Christian/contracted Muslim) using paired *t*-tests. This contrast tested the effect of explicit religious information on face adaptation. There was no significant difference between change scores for the Christian faces when a religious label was given ($t(48.40)= -0.38$, $p= 0.71$, Cohen's $d = 0.04$). However, there was a significant difference for Muslim faces ($t(57.57)=-2.70$, $p= 0.01$, Cohen's $d = 0.65$) when a religious label was given. Change scores in reaction to Muslim faces were in the predicted direction only in the religious explicit condition ($M=-0.87$, $SD=4.45$), but changed in appearance in the same direction as Christian faces in the control condition ($M=2.03$, $SD=4.45$). Thus, for Muslim faces, viewing faces paired with the religious labels reversed the adaption compared to the control condition.

## Discussion

The purpose of study 2 was to test whether adults adapt differently to Christian and Muslim religious faces, when religious labels are explicit compared to when they are absent. Opposing aftereffects were observed in the religious explicit conditions but not in the control conditions. When given religious labels for each face model via audio recordings, the perception of faces shifted, consistent with the expected adaptation. When religion was not made explicit, opposing aftereffects were not observed. This was the first exploration of the effect that religious labels can have on the formation of opposing aftereffects to Christian and Muslim faces.

**Experiment 3: Religious Opposing Aftereffects in 8-year-old's**

Experiment 3 investigated whether, for 8-year-old children, religion is the kind of meaningful social category that can support the formation of opposing aftereffects as with adults. It was hypothesized that children may be able to adapt to religious social categories, similar to previous findings for race opposing aftereffects in children (Short et al., 2011; 2014), though other social factors such as how immersed the child is in their religion may affect how early religious categorization in children emerges (Takriti et al., 2006; Waillet & Roskam, 2012). A between-subjects paradigm was used: half of the children adapted to a storybook consisting of Christian expanded and Muslim contracted faces, and the other half adapted to images distorted in the opposite direction. We modified the methods of experiment 2 to be child-friendly, like previous studies that have successfully observed simple and opposing aftereffects in children of this age

(Anzures et al., 2009; Short et al., 2011, 2014). Children rated the attractiveness of faces along a 5-point cup scale. Faces rated pre- and post-adaptation had stronger intensities than in experiment 2 (+/- 70% compared to +/- 10%). The adaptation phase was presented to children in the form of an electronic storybook. Finally, the faces observed during adaptation were stronger than those used for the adult's adaptation phase in experiment 2 (+/- 90% compared to -/+ 60%) (Anzures et al., 2009).

## Method

### Materials

**Adaptation storybook.** Children were adapted to expanded and contracted Christian and Muslim faces (90%) within the context of a 5-minute electronic storybook. There were two versions of the storybook, one with Christian expanded/Muslim contracted faces, and the other with Christian contracted/Muslim expanded faces as adaptation stimuli. The two storybook versions which were identical except for the directed of distortion. The storybook pages were shown electronically while the experimenter read the story out loud and "flipped pages" via keypress. Children were asked to continuously view and listen. Each page contained between one and seven faces and the size and location of the faces varied. Male and female, and Christian and Muslim faces were balanced throughout the story. Only one religious category was presented on each page and is alternated from page to page.

The story consisted of a Christian boy named Matthew and a Muslim boy named Omar's separate birthday parties. To introduce the two religions throughout the storybook the characters were defined as being either friends with Matthew from church or friends with Omar from Mosque. On pages in which it was Matthew's birthday all of the characters had Christian names and on pages in which it was Omar's birthday the characters had Muslim names. The story began with Matthew and Omar waiting for their guests to arrive. When their guests arrived, they began their separate parties. Throughout the stories the characters played board games, card games, video games, and watched movies, ate popcorn and pizza, opened presents and blew out candles on their cakes.

**Stimuli distortions.** There was an inclusion criterion for the photos used in the storybook stimuli. All of photos were correctly categorized by 81.18% of participants in study 1. All photographs were edited using the spherize function on Adobe Photoshop CS. Each photograph was then expanded by 70% and contracted by 70% for the pre- and post-adaptation stimuli. Pre and post adaptation stimuli consisted of 12 adult faces: 6 Christian and 6 Muslim. The faces were divided into two separate sets of 6 face identities each. Each set consisted of an undistorted, expanded (+70%) and contracted (-70%) Christian and Muslim face. Faces from one set were shown pre-adaptation and faces from the other set were shown post-adaptation. The order was counterbalanced across participants.

Sixteen different faces (8 Christian, 8 Muslim) were used as adaptation stimuli. Adaptation stimuli were distorted by +/- 90%. All faces were edited to only display the head of the individual. See Figure 3a for an example of pre- and post-adaptation stimuli and Figure 3b for examples of the electronic storybook pages.

*Figure 3a.* Pre and post adaptation stimuli examples, Experiment 2: (Left-Right) Christian Male 70% contracted, Christian Female 70% expanded, Christian unaltered, Muslim Male 70% contracted, Muslim female 70% expanded, Muslim unaltered.

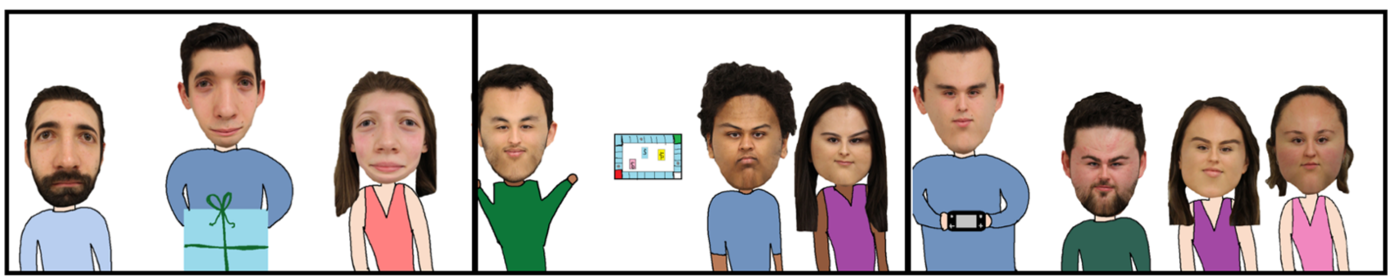


*Figure 3b.* Stimuli examples of the electronic storybook. Faces are altered at +/- 90%.

**Participants**

A total of forty-six 8-year-olds participated in this experiment (+/- 6 months of age, 21 males, *M*= 7.83 years, *SD*=0.38, *range*: 7 years and 7 months - 8 years and 3 months). Sample size was determined based on a previous opposing aftereffect experiment with children as participants (Short et al., 2011). Parents provided written consent and children provided verbal consent. Parents completed a demographic questionnaire about their child's ethnicity, religious heritage, and frequency of religious practice on a scale from 1-5. Two female participants' data were removed from analyses upon the parent's request. Analyses included 26 Christian or Catholic and 2 Muslim children and 16 children whose parents responded non-religious/not applicable. Participants were compensated with $10.

**Procedure**

All trials were conducted on an ASUS 15-inch laptop and children sat 70 cm away from the screen in a laboratory setting. Children were assigned to one of two adaptation conditions: Christian expanded/Muslim contracted faces, or Christian contracted/Muslim expanded faces.

**Practice trials.** A cup scale was used to elicit the children's attractiveness ratings. Practice trials introduced the child to the 5-point cup scale and how to use it in the upcoming trials. Children rated three presents and three balloons that varied in attractiveness. They were shown each present individually, in a randomized order, and had unlimited time to view and rate each present. The same methods were followed for the balloons. For this and all subsequent trials the largest cup meant very, very attractive and the smallest cup meant not attractive at all.

**Pre-adaptation phase.** Children were told that they were going to see pictures of children who would be attending a birthday party and that their job was to rate how attractive each face was. Each child viewed 6 faces (3 Muslim and 3 Christian) at each level of distortion. The first 2 faces presented were always undistorted, and the following faces were randomized. Each face appeared on the screen for 3 seconds. After 3 seconds the face disappeared, and the cup scale appeared. Children had unlimited time to select their answer via keypress.

**Adaptation phase.** Participants were asked to view and listen to the electronic story about the birthday parties of Matthew and Omar. The storybook was read out loud by the experimenter. Throughout the story children viewed Christian and Muslim faces that had been distorted by 90%. The entire story was 5 minutes.

**Post adaptation phase**. At the end of the storybook, participants were told that 6 guests had arrived late. Participants were shown an additional six faces from the second face set and asked to rate the faces using the same methodology in the pre-adaptation trial. After rating each face two top-up faces were presented. Top-up faces were distorted consistent with the adaptation direction for each condition. The first top-up face matched the religion of the previous trial, and the second matched the religion of the next trial. Top-up faces were paired with an encouraging voice, the first top-up face said, "Great job!" and the second said, "I think so too!".

## Results

Mean attractiveness ratings were calculated for all distorted faces (+70% and – 70%, Christian and Muslim) pre- and post-adaptation, and change scores were calculated by subtracting the rating of pre-adaptation from the rating from post adaptation.

As change scores are influenced by pre-adaptation ratings, we first examined whether there were differences in the pre-adaptation ratings for either of the distortion levels or adaptation conditions. A 2 (adaptation condition: expanded Christian/contracted Muslim or contracted Christian/expanded Muslim) by 2 (distortion: +70% or -70%) repeated-measures ANOVA for the pre-adaptation ratings revealed no main effect of distortion ($F(1,42)=0.27$, $p= 0.605$), adaptation condition ($F(1,42)=0.90$, $p= 0.35$), or condition by distortion interaction ($F(1,42)=0.38$, $p= 0.55$).

### Examination of Both Adaptation Conditions

For the main analysis, a 2 (religion: Muslim or Christian) by 2 (distortion: +70% or -70%) by 2 (adaptation condition: expanded Christian/contracted Muslim or contracted Christian/expanded Muslim) mixed ANOVA with adaptation condition as the between subject's variable and mean change scores as the dependent variable was conducted to determine if opposing aftereffects were present. There was no main effect of adaptation condition ($F(1, 42)= 1.92$, $p=$

0.17), distortion ($F(1, 42)= 1.68$, $p=0.20$), or religion ($F(1,42)=0.55$, $p=0.46$). There was a significant religion by distortion interaction ($F(1,42)= 9.67$, $p= 0.003$, $\eta_p^2 = 0.19$), but no significant interaction of condition and distortion ($F(1,42)= 0.79$, $p= 0.38$), condition and religion ($F(1,42)= 0.10$, $p= 0.76$) or condition, distortion and religion ($F(1,42)= 1.80$, $p= 0.19$). Opposing aftereffects were not observed as change scores did not differ based on condition, distortion, and religion.

Paired *t*-tests examined the distortion by religion interaction. After correcting for multiple comparisons, the alpha level was set at 0.0083. Contracted Christian faces ($M$=1.36, $SD$=1.62) resulted in significantly more change in attractiveness ratings than contracted Muslim faces ($M$=0.32, $SD$=1.33), ($t(43)=3.07$, $p=0.004$, Cohen's $d = 0.70$) over both adaptation conditions. All other pairings were not significant ($p$s> 0.012). See Figure 4.

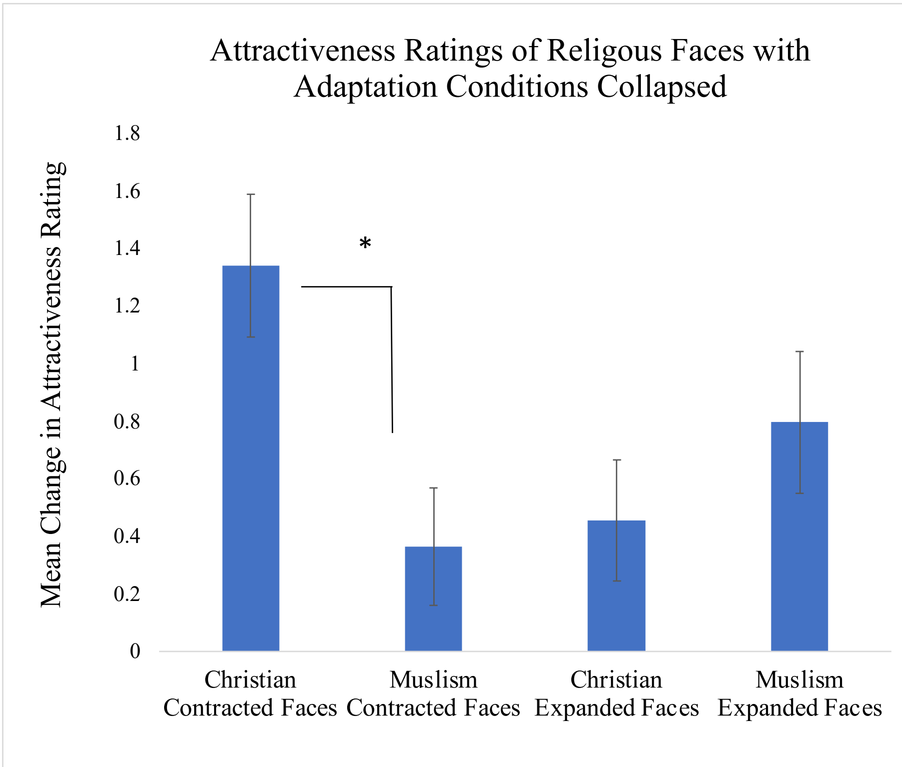



*Figure 4.* Mean change in attractiveness ratings of Christian and Muslim expanded and contracted faces for both adaptation conditions collapsed, for 8 experiment 3.

## Discussion

The purpose of experiment 3 was to test whether for 8-year-old children religion is the kind of meaningful social category that can support the formation of opposing aftereffects as found in adults in experiment 2. In contrast to adults, religion-based opposing aftereffects were not observed in 8-year-olds.

## General Discussion

In experiment 2, participants who adapted to Christian contracted and Muslim expanded faces paired with audio recordings that made religious membership explicit showed evidence of opposing aftereffects: the preference for contracted Christian faces increased after adaptation, and preference for Muslim contracted faces decreased. Even when data from the 2 most misidentified female models viewed were examined individually, opposing aftereffects were observed. This is the first evidence we know of opposing aftereffects across religious-based categories, and the first time that information delivered via audio recordings has been shown to impact whether opposing aftereffects form. Religious categories may serve as the kind of meaningful social category necessary for the formation of opposing aftereffects, but only if such category membership is made explicitly.

Others have reported opposing aftereffects in adults across race and gender categories without the use of audio labels to enhance the meaning of the faces presented (Jaquet et al., 2008; Little et al., 2005; Little et al., 2008). The current results differ markedly because the opposing aftereffects were induced only among participants who heard religious labels and explicit religious descriptions. As the control trials resulted in no aftereffects, whatever physical similarities the two sets of images shared based on race, ethnicity, or country of birth, were not distinct enough to evoke an aftereffect on their own. Studies showing opposing aftereffects across race and gender categories have induced these aftereffects without making explicit the race or gender of the models (Jaquet et al., 2008; Little et al., 2005; Little et al., 2008). This suggests that race and gender were both physically distinct and socially meaningful enough based on visual information available in the faces alone. A clear conclusion is that the categories of race and religion are not psychologically equivalent. The difference may be that, although our image sets were correctly sorted in Experiment 1, religious categories may lack a visually perceivable social distinction until the social information is explicitly labeled.

One important implication of these results is that information presented in the auditory domain appears to impact visual processing. In the control condition, fixating on faces that had been manipulated differently depending on the model's religious category did not result in opposing aftereffects. In the experimental condition, religious information was introduced only in the auditory domain. This implies top-down visual perception of the face stimuli.

Previous research suggests that two arbitrary categories alone cannot support the formation of opposing aftereffects. Apparently, two categories have to be sufficiently socially meaningful in order for opposing aftereffects to form (Short & Mondloch, 2010). Results from the current study suggest that religion is the type of social category that can support the formation of opposing aftereffects, but not that religion is unique in this respect. It is very possible that numerous other social categories might also be the type of social categories that could support the formation of opposing aftereffects. For example, would opposing aftereffects result if explicit labels described ethnicity, nation-of-origin, or preference for a regionally specific cuisine? This study was not designed to distinguish between religion and other types of social categories, but future research could shed light on other social categories that support the formation of opposing aftereffects.

**Children's developing understanding of religion**

In experiment 3, opposing aftereffects for religion were not observed in 8-year-olds, suggesting either immaturity in the development of religious face templates or in the participants' understanding of religion. Unlike adults, 8-year-olds did not show evidence of opposing aftereffects even when the religion of the faces is made explicit. Our predominantly Caucasian sample only showed evidence of adapting to Christian faces. These results are similar to Short et al., (2014)'s examination of race aftereffects in 5-year-olds, in which their predominantly Caucasian sample only adapted to Caucasian faces. Results from experiment 3 suggest that the opposing aftereffects observed in adults in experiment 2 may not develop until after the age of 8.

It is not clear when children come to view religious groups as social categories. Some researchers suggest that children begin to understand differences between religions around 8 or 9 years of age (Elkind, 1964; Quintana, 1998). How immersed a child is in their own religion, and how aware they are of other types of religions impacts a child's understanding of the religious groups we examined (Waillet & Roskam, 2012). If a child does not recognize the religious groups presented in this experiment, aftereffects would not be predicted.

Children's face space is still developing at 8 years of age, and it is possible that as with race (Short et al., 2014), religious opposing aftereffects across religious categories will not be evident until later. It also is possible that the physical differences between the Christian and the Muslim faces were not perceived as categorically distinct at this age. If the face sets are not perceptually distinct to the observer, opposing aftereffects would not be predicted. Furthermore, although the relationship between religion and coalitional psychology was presented with stark contrast for the sake of the experimental design, how children view religious "out groups" may vary based on where they are raised, and their perception of these "out groups" could still be developing.

**Influence of physical disctiviness and social meaning**

In order to evoke aftereffects, faces must be physically distinct across categories (Armann et al., 2011; Short & Mondloch, 2010). The purpose of experiment 1 was to ensure that the Christian and Muslim faces could be accurately categorized based on the model's self-identified religion. Over 80% of the faces were accurately categorized, and only 4 faces were misidentified by half of the participants. These 4 were the most miscategorized faces and were not included in test trials in experiment 2 and 3, ensuring that the stimuli consisted of face sets which could be categorized by religion based on visual cues in experiment 2.

**Limitations**

Previous studies have suggested that some computer distorted stimuli may be perceived as less perceptually distorted than others (Robbins, Maurer, Hatry, Anzures, & Mondloch, 2012; Robbins, McKone, & Edwards, 2007). In experiment 2, it is possible that the Christian expanded, and Muslim contracted stimuli may have been perceived as less distinct or distorted than the Christian contracted and Muslim expanded faces stimuli, resulting in weaker aftereffects. Additionally, in experiment 2 the Muslim contracted faces were perceived differently than Christian contracted faces, possibly affecting the Christian expanded Muslim contracted adaptation condition. This condition did not yield opposing aftereffects when faces were paired with religious explicit audio. The potential perceptual difference between viewing Muslim contracted faces and Christian contracted faces further explains the differences in opposing aftereffects for both of the religious explicit adaptation conditions.

In experiment 3, children perceived Christian contracted faces as more attractive than the Muslim contracted faces. It is possible that the Muslim contracted faces were seen as less distorted than the Christian contracted faces. Similar results have been observed in 10-year-old children who perceived inverted distorted faces as less distorted than up-right distorted faces (Robbins, Maurer, Hatry, Anzures, & Mondloch, 2012) whereas adults' were capable of simultaneously adapting to opposing aftereffects for inverted faces (Rhodes et al., 2004; Robbins et al., 2012; Watson & Clifford, 2006). The majority of our sample in experiment 3 consisted of self-identified Christian, Catholic or non-practicing children. It is possible that Christian and Muslim children who are exposed to multiple religions might show differing results than the children in our sample as the religious categories may be more socially meaningful. Future research should examine both Christian and Muslim children and children who have a broad religious education.

**Future Directions**

This project is an early step towards understanding the relationship between face perception and religious-based social categorization. The current study suggests that religious social groups are in fact meaningful enough to evoke opposing aftereffects when relevant social information is provided. Experiment 2 provides evidence that religious categorization impacts face perception, because opposing aftereffects are evident only in trials in which the model's religion is made evident via audio labels, and not in trials in which the same models are not described in religious terms. It does not, however, allow us to infer whether these faces would be perceived categorically in the absence of any audio stimuli. It is unclear whether the religious audio label enhanced adaptation or if the control audio impeded adaptation. Future studies could re-test these models with no accompanying audio information, in order to estimate a "baseline" adaptation for comparison in order to disambiguate the direction of the effect.

Future examination could also explore a perceptually ambiguous face set and manipulating the religious labels between subjects via audio labels. By adapting one set of participants to faces labeled Christian and another set labeled Muslim, one could further explore this effect of social labeling Christian and Muslim faces independent of perceptual cues. Additionally, the same faces as in the current study could be explored with the use of other labels, like an ethnic label, or a nationality, or preferred foods, to determine if adaptation occurs with and without these social labels.

## Conclusion

The purpose of this study was to examine whether opposing religious aftereffects across Christian and Muslim face sets could be induced in adults and children. Experiment 2 was the first study to demonstrate opposing aftereffects for Christian and Muslim faces. Opposing aftereffects were observed when religious categories were made explicit via audio descriptions. In experiment 3, 8-year-old children showed no evidence of opposing aftereffects for Christian and Muslim faces. Eight-years-olds may be immature with respect to face template development or an understanding of religion as a social category.

## References

Anderson, N. D., & Wilson, H. R. (2005). The nature of synthetic face adaptation. *Vision Research*, *45*(14), 1815–1828. https://doi.org/10.1016/j.visres.2005.01.012

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face Adaptation and Attractiveness Aftereffects in 8-Year-Olds and Adults. *Child Development*, *80*(1), 178–191.

Armann, R., Jeffery, L., Calder, A. J., & Rhodes, G. (2011). Race-specific norms for coding face identity and a functional role for norms. *Journal of Vision*, *11*(13), 9–9. https://doi.org/10.1167/11.13.9

Bail, C. A. (2014). *Terrified: How anti-Muslim fringe organizations became mainstream*. Princeton University Press.

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Canadian University Survey Consortium. (n.d.). *Canadian University Survey Consortium*. Retrieved December 9, 2020, from https://cusc-ccreu.ca/?page_id=32&lang=en

Clifford, C. W. G., & Rhodes, G. (2005). *Fitting the Mind to the World: Adaptation and After-Effects in High-Level Vision*. OUP Oxford.

Fox, C. J., & Barton, J. J. S. (2007). What is adapted in face adaptation? The neural representations of expression in the human visual system. *Brain Research*, *1127*, 80–89. https://doi.org/10.1016/j.brainres.2006.09.104

Grosfoguel, R. (2012). The multiple faces of Islamophobia. *Islamophobia Studies Journal*, *1*(1), 9–33.

Hall, D. L., Cohen, A. B., Meyer, K. K., Varley, A. H., & Brewer, G. A. (2015). Costly Signaling Increases Trust, Even Across Religious Affiliations. *Psychological Science*, *26*(9), 1368–1376. https://doi.org/10.1177/0956797615576473

Husain, N. (2018). *Timeline: Legal fight over Trump's "Muslim ban" and the Supreme Court ruling*. Chicagotribune.Com. Retrieved December 15, 2020, from https://www.chicagotribune.com/data/ct-travel-ban-ruling-timeline-htmlstory.html

Ito, T. A., & Urland, G. R. (2003). Race and gender on the brain: Electrocortical measures of attention to the race and gender of multiply categorizable individuals. *Journal of Personality and Social Psychology*, *85*(4), 616–626. https://doi.org/10.1037/0022-3514.85.4.616

Ito, T. A., & Urland, G. R. (2005). The influence of processing objectives on the perception of faces: An ERP study of race and gender perception. *Cognitive, Affective, & Behavioral Neuroscience*, *5*(1), 21–36. https://doi.org/10.3758/CABN.5.1.21

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Johnson, K. A., Li, Y. J., & Cohen, A. B. (2015). Fundamental social motives and the varieties of religious experience. *Religion, Brain & Behavior*, *5*(3), 197–231.

Johnson, M. K., Rowatt, W. C., & LaBouff, J. P. (2012). Religiosity and prejudice revisited: In-group favoritism, out-group derogation, or both? *Psychology of Religion and Spirituality*, *4*(2), 154.

LaBouff, J. P., Rowatt, W. C., Johnson, M. K., & Finkle, C. (2012). Differences in Attitudes Toward Outgroups in Religious and Nonreligious Contexts in a Multinational Sample: A Situational Context Priming Study. *The International Journal for the Psychology of Religion*, *22*(1), 1–9. https://doi.org/10.1080/10508619.2012.634778

Langlois, J. H., & Roggman, L. A. (1990). Attractive Faces Are Only Average. *Psychological Science*, *1*(2), 115–121. https://doi.org/10.1111/j.1467-9280.1990.tb00079.x

Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature Neuroscience*, *4*(1), 89–94. https://doi.org/10.1038/82947

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces.

*Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

McCullough, M. E., Swartwout, P., Shaver, J. H., Carter, E. C., & Sosis, R. (2016). Christian religious badges instill trust in Christian and non-Christian perceivers. *Psychology of Religion and Spirituality*, *8*(2), 149–163. https://doi.org/10.1037/rel0000045

Mouchetant-Rostaing, Y., Giard, M.-H., Bentin, S., Aguera, P.-E., & Pernier, J. (2000). Neurophysiological correlates of face gender processing in humans. *European Journal of Neuroscience*, *12*(1), 303–310. https://doi.org/10.1046/j.1460-9568.2000.00888.x

Nishimura, M., Maurer, D., Jeffery, L., Pellicano, E., & Rhodes, G. (2008). Fitting the child's mind to the world: Adaptive norm-based coding of facial identity in 8-year-olds. *Developmental Science*, *11*(4), 620–627. https://doi.org/10.1111/j.1467-7687.2008.00706.x

Peek, L. (2011). *Behind the backlash: Muslim Americans after 9/11*. Temple University Press.

Pew Research Centre, Washington, S. 800, & Inquiries, D. 20036 U.-419-4300 | M.-419-4349 | F.-419-4372 | M. (2017, April 5). The Changing Global

Religious Landscape. *Pew Research Center's Religion & Public Life Project*. https://www.pewforum.org/2017/04/05/the-changing-global-religious-landscape/

Potter, T., & Corneille, O. (2008). Locating attractiveness in the face space: Faces are more attractive when closer to their group prototype. *Psychonomic Bulletin & Review*, *15*(3), 615–622. https://doi.org/10.3758/PBR.15.3.615

Raiya, H. A., Pargament, K. I., Mahoney, A., & Trevino, K. (2008). When Muslims are perceived as a religious threat: Examining the connection between desecration, religious coping, and anti-Muslim attitudes. *Basic and Applied Social Psychology, 30*, 311–325.

Rhodes, G., & Jeffery, L. (2006). Adaptive norm-based coding of facial identity. *Vision Research*, *46*(18), 2977–2987.

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., & Nakayama, K. (2003). Fitting the Mind to the World: Face Adaptation and Attractiveness Aftereffects. *Psychological Science*, *14*(6), 558–566.

Rhodes, G., Jeffery, L., Watson, T. L., Jaquet, E., Winkler, C., & Clifford, C. W. (2004). Orientation-contingent face aftereffects and implications for face-coding mechanisms. *Current Biology*, *14*(23), 2119–2123.

Rhodes, G., & Tremewan, T. (1996). Averageness, Exaggeration, and Facial Attractiveness. *Psychological Science*, *7*(2), 105–110. JSTOR.

Robbins, R. A., Maurer, D., Hatry, A., Anzures, G., & Mondloch, C. J. (2012). Effects of normal and abnormal visual experience on the development of opposing aftereffects for upright and inverted faces. *Developmental Science*, *15*(2), 194–203. https://doi.org/10.1111/j.1467-7687.2011.01116.x

Robbins, R., McKone, E., & Edwards, M. (2007). Aftereffects for face attributes with different natural variability: Adapter position effects and neural models. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(3), 570–592. https://doi.org/10.1037/0096-1523.33.3.570

Said, E. W., & Laade, W. (1978). *Orientalism*. Routledge & Kegan.

Short, L. A., Hatry, A. J., & Mondloch, C. J. (2011). The development of norm-based coding and race-specific face prototypes: An examination of 5- and 8-year-olds' face space. *Journal of Experimental Child Psychology*, *108*(2), 338–357. http://dx.doi.org.libaccess.lib.mcmaster.ca/10.1016/j.jecp.2010.07.007

Short, L. A., Lee, K., Fu, G., & Mondloch, C. J. (2014). Category-specific face prototypes are emerging, but not yet mature, in 5-year-old children. *Journal of Experimental Child Psychology*, *126*, 161–177. https://doi.org/10.1016/j.jecp.2014.04.004

Short, L. A., & Mondloch, C. J. (2010). The Importance of Social Factors is a Matter of Perception. *Perception*, *39*(11), 1562–1564. https://doi.org/10.1068/p6758

Strabac, Z., & Listhaug, O. (2008). Anti-Muslim prejudice in Europe: A multilevel analysis of survey data from 30 countries. *Social Science Research, 37*, 268–286

Takriti, R. A., Barrett, M., & Buchanan-Barrow, E. (2006). Children's understanding of religion: Interviews with Arab-Muslim, Asian-Muslim, Christian and Hindu children aged 5–11 years. *Mental Health, Religion & Culture*, *9*(1), 29–42. https://doi.org/10.1080/13674670512331335677

Tomelleri, S., & Castelli, L. (2011). On the Nature of Gender Categorization. *Social Psychology*, *43*(1), 14–27. https://doi.org/10.1027/1864-9335/a000076

Valentine, T. (1991). A Unified Account of the Effects of Distinctiveness, Inversion, and Race in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *43*(2), 161–204. https://doi.org/10.1080/14640749108400966

Valentine, T., Darling, S., & Donnelly, M. (2004). Why are average faces attractive? The effect of view and averageness on the attractiveness of female faces. *Psychonomic Bulletin & Review*, *11*(3), 482–487. https://doi.org/10.3758/BF03196599

Waillet, N. van der S., & Roskam, I. (2012). Developmental and Social Determinants of Religious Social Categorization. *The Journal of Genetic Psychology*, *173*(2), 208–220. https://doi.org/10.1080/00221325.2011.600356

Watson, T. L., & Clifford, C. W. G. (2006). Orientation dependence of the orientation-contingent face aftereffect. *Vision Research*, *46*(20), 3422–3429. https://doi.org/10.1016/j.visres.2006.03.026

Webster, M. A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature*, *428*(6982), 557. https://doi.org/10.1038/nature02420

Webster, M. A., & Maclin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review*, *6*(4), 647–653. https://doi.org/10.3758/BF03212974

# Chapter 4:

## Opposing aftereffects between a White Male face set and a diverse face set

Foglia, V., & Rutherford, M.D. (Under review) Opposing aftereffects between a White Male face set and a diverse face set. Submitted to: *Vision Research* – Manuscript ID: VR-20-310

## Preface

Aftereffects are useful tools to investigate the representation of face space. It has been proposed that adults rely on cognitive face norms to aid face perception (Valentine, 1991). More recently evidence for category-contingent face templates has been supported via opposing aftereffects. This paradigm consists of adapting to two separate categories of faces, distorted in opposite directions (Bestelmeyer et al., 2008; Little et al., 2005). After adaptation, attractiveness judgements must shift in the direction of adaptation for both of the categories in order to provide evidence of separate norms. Adults have separate face norms for several categories such as: race (Bestelmeyer et al., 2010; Jaquet et al., 2008), sex (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Watson & Clifford, 2006), and age (Little et al., 2008; Schweinberger et al., 2010).

Opposing aftereffects rely on adaptation stimuli meeting two requirements: the stimuli must come from socially significant categories and consist of physical differences between the faces (Bestelmeyer et al., 2008; Short & Mondloch, 2010). Most commonly, when examining category-contingent aftereffects the physical differences only vary on one categorical dimension (i.e., Male/Female, Asian/White, Human/Ape (Bestelmeyer et al., 2008; Jaquet & Rhodes, 2008; Little et al., 2008). For example, when adapting to separate gendered faces they are all of the same race, and no other physical differences are manipulated. Additionally, race contingent aftereffects have been explored frequently (Armann, Jeffery, Calder, & Rhodes, 2011; Jaquet, Rhodes, & Hayward, 2008; Little et al., 2008) but no examination has varied the race of the individuals within an adapting face set.

This chapter was designed to test two novel pieces of information about adaptation and face space: 1) whether it is possible to adapt to a category of faces that vary physically within a group and 2) whether diversity itself is a cue to category membership and thus supports the formation of face templates. Participants adapted to contracted and expanded diverse and homogenous face sets via an opposing aftereffects paradigm. The diverse face set consisted of White, Latinx, Black, Asian, male and female faces, manipulating the ability to adapt to a race and gender diverse group. The homogenous face set consisted of only White males.

Through this first examination of the ability to adapt to diverse faces, opposing aftereffects were observed. These results suggest the ability to adapt to a diverse face set as a separate social category from a homogenous set. As social significance was not manipulated beyond the visibility of the faces, diversity was a cue to category membership and facilitated the separation of face templates. Implications of this chapter consist of novel knowledge on the ability to manipulate physical dissimilarity within adaptation sets, information that will be beneficial for those who commonly utilize face adaptation techniques. Not only did this chapter reveal the ability to adapt to faces that differ vastly via opposing aftereffects paradigm, but it also uncovered another example of separate face templates in adults. This chapter revealed new information about how our face space represents groups of faces, an area not yet explored.

**References**

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. https://doi.org/10.1080/13506280802708024

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Schweinberger, S. R., Zäske, R., Walther, C., Golle, J., Kovács, G., & Wiese, H. (2010). Young without plastic surgery: Perceptual adaptation to the age of female and male faces. *Vision Research*, *50*(23), 2570–2576. https://doi.org/10.1016/j.visres.2010.08.017

Short, L. A., & Mondloch, C. J. (2010). The Importance of Social Factors is a Matter of Perception. *Perception*, *39*(11), 1562–1564. https://doi.org/10.1068/p6758

Valentine, T. (1991). A Unified Account of the Effects of Distinctiveness, Inversion, and Race in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *43*(2), 161–204. https://doi.org/10.1080/14640749108400966

Watson, T. L., & Clifford, C. W. G. (2006). Orientation dependence of the orientation-contingent face aftereffect. *Vision Research*, *46*(20), 3422–3429. https://doi.org/10.1016/j.visres.2006.03.026

**Abstract**

Opposing aftereffects have been observed for faces categorized by gender, race, and age. In order to form opposing aftereffects, it appears that the two face sets must be both physically distinct and differ in terms of social meaning. The current study tested whether 1) a face set that is diverse with respect to sex and race can produce a coherent aftereffect and 2) whether this diversity itself is socially meaningful enough to support opposing aftereffects. Participants adapted to a homogenous face set consisting of only White male Republican congressmen and a diverse face set consisting of White, Asian, Black, and Latinx male and female Democratic congress members. Opposing aftereffects were observed: participants adapted simultaneously and in opposite directions to the face sets. These results were the first evidence of adaptation to a face set that varies based on race and sex, and the first evidence of diversity being perceived as a socially meaningful category marker.

***Keywords:*** *aftereffects, diversity, face perception, opposing aftereffects*

## 1. Introduction

Aftereffects have been called the “psychologists’ microelectrode” for their ability to reveal how stimuli are represented in the brain (Frisby, 1979). A visual aftereffect is a short-term change to the perception of a stimulus after fixating on the adapting stimulus, as when a white surface appears green after a period of fixating on a red stimulus. The process of adaptation temporarily alters the perceptual system (Clifford & Rhodes, 2005; Webster, 2011). A classic example is the waterfall illusion, in which observers adapt to a waterfall that is moving downward, then view a stationary image of a waterfall that appears to move upwards (Mather, Verstraten & Anstis, 1998). Visual aftereffects have been found for orientation (Clifford, 2002), colour (Gurnsey, Bryden & Humphrey, 1994; Thompson & Latchford, 1986), size (Blakemore & Sutton, 1969; Sutherland, 1961), and shape (Suzuki, 2003).

Visual aftereffects have been observed using complex stimuli such as faces, as when the face has been experimentally altered (Leopold, Rhodes, Müller, & Jeffery, 2005; Watson & Clifford, 2003; Webster & Maclin, 1999). For example, after continuously viewing faces with digitally contracted face features, an unaltered face will appear expanded (Leopold, O'Toole, Vetter, & Blanz, 2001). This type of face adaptation is a simple aftereffect (Jaquet & Rhodes, 2008). Simple aftereffects have been observed for identity (Leopold et al., 2001; Rhodes & Jeffery, 2006; Rhodes & Leopold, 2011), attractiveness (Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003), race (Webster, Kaping, Mizokami, &

Duhamel 2004), gender (Rhodes, Jeffery, Watson, Jaquet, Winkler, & Clifford, 2004; Webster et al., 2004), and emotion (Webster et al., 2004), and are taken as evidence of norm-based coding (Rhodes et al., 2003; Rhodes & Leopold, 2011; Webster et al., 2004).

In opposing aftereffects experiments, participants are adapted simultaneously to two separate face categories that have been physically distorted in the opposite directions, for example, male contracted, and female expanded faces (Jaquet & Rhodes, 2008; Jaquet, Rhodes, & Hayworth, 2008; Rhodes et al., 2004; Little, DeBruine, Jones, & Waitt, 2008). If attractiveness or normality selections shift in the direction of adaptation for both categories, opposing aftereffects have been found. Opposing aftereffects are taken as evidence that the face categories are processed using discrete neural representations (Jaquet, Rhodes, & Hayward, 2008). Opposing aftereffects have been observed for race (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008), gender (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, & Jones, 2005), age, and species (Little et al., 2008).

Two criteria appear to be prerequisites in evoking opposing aftereffects, 1) the two face sets must be physically distinct and 2) the face sets must be socially meaningful. Short and Mondloch (2010) tested whether opposing aftereffects could occur between two face sets without physical differences. Artificial “in groups” or “out groups” based on purported shared personality traits were created to form a meaningful social distinction while maintaining physical similarity between the two face sets. Opposing aftereffects were not observed, suggesting that face categories must be physically different as well as socially meaningful to evoke opposing aftereffects. In contrast, Bestelmeyer, Jones, DeBruine, Little, Perrett, Schneider, Welling, and Conway (2008) examined whether physical differences could evoke opposing aftereffects in the absence of a socially meaningful category distinction by controlling for physical dissimilarity across a socially distinct and a less socially distinct pair of face sets. Opposing aftereffects were observed across the male and female face sets but not across the female and hyper-female faces face sets, even though the physical dissimilarity was equated. These results suggested that the female and hyper-female face sets were not socially distinct in the manner that supports opposing aftereffects, while the male and female sets were.

While it is believed that face sets must be different with respect to social meaning, there has been very little work exploring what constitutes a socially meaningful distinction, although we know that both sex and race support opposing aftereffects. It is possible that the diversity of a face set, with respect to sex and race, may be a meaningful cue to social category membership, if the diversity itself serves as a cue to a cultural competence among group members. Commonly, opposing aftereffect experiments consist of two distinct, but homogeneous face sets (i.e. Male/Female, Asian/White, Human/Ape (Bestelmeyer et al., 2008; Jaquet & Rhodes, 2008; Little et al., 2008). Previously no examination of race contingent aftereffects (Armann, Jeffery, Calder, &

Rhodes, 2011; Jaquet, Rhodes, & Hayward, 2008; Little et al., 2008) has varied the races of the individuals within an adapting face set and have only compared whether it is possible to adapt to two separate race categories at one time. Little is known about how the diversity of a face set may affect aftereffects, how diversity is perceived categorically, and whether it can be perceived as one uniform social group.

### 1.1 Current Study

The current study is designed to test 1) whether it is possible to adapt to a category of faces that vary physically within a group and 2) whether diversity itself is a cue to category membership and thus supports the formation of face adaptation. Using an opposing aftereffects paradigm, participants adapted to either a contracted diverse face set and expanded homogenous face set or to an expanded diverse face set and contracted homogenous face set.

Diverse and homogenous face sets depicted elected members of the U.S. House of Representatives as of 2019. The homogenous face sets consist only of White male Republican Members of the House of Representatives. The diverse face set is a balanced sample of White, Latinx, Black, and Asian men and women. These face sets were selected as they parallel the largely homogeneous Republican party and the relatively diverse Democratic party. The proportion of White men in the Democratic caucus is 38% percent, whereas the proportion of White men in the Republican caucus is 90% (Jacobs, 2018). Fifty-two of the Black House Members are Democrats, and one is Republican, 37 of all Latinx or

Hispanic members are Democrats and eight are Republican and 16 of all Asian representatives are Democratic while one is Republican (Manning, 2019). With respect to gender, 90 of the 105 female House members belong to the Democratic party, and the remaining 15 are Republican (Manning, 2019). Given this demographic distinction between the two parties, it is possible that diversity itself may be a cue to party membership. This is the first test of whether it is possible to adapt to a face set that varies in terms of physical characteristics. It is also the first examination as to how diverse face groups are perceived categorically in an opposing aftereffects paradigm.

## 2. Methods

### 2.1 Materials

#### 2.1.1 Visual Stimuli.

Forty-eight official portraits of current members of the United States Congress were obtained from a Wikipedia list of current congress members serving in the House of Representatives on June 17, 2019 ("List of Current Members of the United States House of Representatives," 2019). From these portraits, a homogenous face set of 16 White Male Republicans and a diverse face set of 16 White, Latinx (Bednar & Miikkulainen, 2000; Gibson, 1933; Köhler & Wallach, 1944), Black, and Asian male and female Democrats were selected. The diverse face set included 4 each of White, Latinx, Black, and Asian faces, including 2 male and 2 female faces for each race. Congress members who were likely to be recognized by the participant due to media exposure were not included. Selecting by the party was intended to maintain ecological validity. For a full list of the names of the Members of Congress used as visual stimuli see Appendix A.

The faces were edited in Adobe Photoshop CS using a 4 by 5 aspect ratio so that images consisted of only the face, hair, and neck of each individual. A maximum resolution was maintained. Then each photo was edited to 3 cm by 4 cm with 300 pixels per inch. Finally, distortions were formed for each photo by expanding 10% and 60% and contracting 10% and 60% each using the spherize function including all of the facial features.

#### 2.1.2 Audio Stimuli.

The audio stimuli to be played during pre-adaptation and post-adaptation or adaptation phases were recorded using the Voice Recorder Audio Editor cellphone application. The audio stimuli played during pre- and post-adaptation only stated the congressperson's name. The Audio recordings played during the adaptation phase stated the congressperson's name and the year when they entered office, for example, "Karen Bass entered office in 2017".

### 2.2 Procedure

Participants were randomly assigned to one of two conditions: 1) contracted homogenous/expanded diverse or 2) expanded homogenous /contracted diverse. Both of the conditions followed the same procedure but with opposite distortion during the adaptation trials. The procedure consisted of a pre-adaptation, an adaptation, and a post-adaptation phase. The audio stimuli were identical across conditions. Each face image was presented on a 15-inch ASUS laptop with the participant 25 inches away from the screen. Ethics approval was obtained from McMaster Research Ethics Board and informed consent was obtained from each participant before the experiment began.

**2.2.1 Pre-adaptation phase.**

The purpose of this phase was to measure baseline face perception prior to any adaptation. Participants viewed a total of 64 face pairs for three seconds each. Each pair consisted of the same individual with one image expanded 10% and the other image contracted 10%. Pairs were displayed four times each, balancing the left-right placement of the expanded and contracted faces in a randomized order. These 64 trials comprised 16 face pairs. Eight face pairs were from the homogenous face set and eight faces were from the diverse face set. Each face pair was presented with an audio clip stating the congressperson's name.

Participants were asked to select which of the two faces was most attractive. Participants pressed the "F" key if the face on the left was more attractive and the "J" key if the face on the right was more attractive. Participants had unlimited time to respond, and once a selection was made, they were shown the next pair.

**2.2.2 Adaptation phase.**

Participants adapted to 32 faces, presented one at a time for six seconds each with an interstimulus interval of 500 milliseconds. Each face was only presented once. Of the 32 faces, 16 were from the homogenous face set and sixteen were from the diverse face set.

### 2.2.3 Post-adaptation phase.

The post-adaptation phase was almost identical to the pre-adaptation phase except that top-up faces were presented in between each face pair, and face pairs were presented in a newly randomized order. The top-up faces were intended to maintain the adaptation throughout the post-adaptation phase and were the same faces that the participant saw in the adaptation phase but without audio clips.

### 2.2.4 Demographics and Questionnaires

Following the experimental phases, participants were asked to fill out a demographic questionnaire. The questionnaire asked their age, sex, ethnicity, citizenship, whether they recognized any of the faces, which party they typically vote for in Canada, which party they would vote for if they could in the United States, how closely they follow American and Canadian politics, whether they typically vote, and who they vote for.

## 3. Results

Sixty-five participants took part in the experiment. One participant was not included due to a computer error resulting in incomplete data collection. Sixty-four participants were included in the analyses. The final sample consisted of 30 males and 34 females with a mean age of 18.32 years (range: 17-35, $SD$=2.20). Participants received partial course credit. The sample size was selected based on previous aftereffects studies indicating that approximately 30 participants per adaptation condition are sufficient in exploring opposing aftereffects

(Bestelmeyer et al., 2008; Bestelmeyer et al., 2010; Little et al., 2011; Short & Mondloch, 2010).

Before the main analyses, we examined whether the two adaptation conditions were matched on political knowledge. Participants' average self-rated knowledge of Canadian politics was 2.06 and 2.00 for American politics on a scale from 1-5, with 5 being the most knowledgeable. A one-way ANOVA revealed no differences between adaptation condition and the amount of knowledge participants have of Canadian politics ($F(1,62)=1.458$, $p=0.232$) (expanded homogenous /contracted diverse: $M=2.00$, $SD=1.25$, contracted homogenous/expanded diverse: $M=2.03$, $SD=$1.2=06), or American politics ($F(1,62)=0.046$, $p=0.830$) (expanded homogenous /contracted diverse: $M=2.16$, $SD=1.02$, contracted homogenous/expanded diverse: $M=1.84$, $SD=1.05$) (see Table 1 for all demographic information).

**Table 1.** Demographics and political questionnaire information

| | Participants (*N*= 64) |
|---|---|
| Sex | |
| Males | 30 |
| Females | 34 |
| Age | |
| Average | 18.32 |
| Standard deviation | 2.20 |
| Range | 17-35 |
| Average knowledge of Canadian politics | 2.06 |
| Average knowledge of American politics | 2.00 |
| Do you typically vote? | |
| Yes | 40 |
| No | 9 |
| Too young to vote | 15 |
| Canadian political party that most closely encompasses your values | |
| Liberal | 24 |
| NDP | 16 |
| Conservative | 12 |
| Green | 1 |
| I don’t know or blank | 11 |
| American political party that most closely encompasses your values | |
| Democratic | 30 |
| Republican | 10 |
| I don’t know or blank | 24 |

For the main analyses, adaptation was quantified using each participant's change score, calculated by subtracting the number of contracted faces selected post-adaptation from the number of contracted faces selected pre-adaptation. A 2 (adaptation condition: adapted to expanded homogenous faces/contracted diverse or contracted homogenous/expanded diverse) by 2 (face set: homogenous or diverse test face) mixed ANOVA was conducted. The adaptation condition was the between subjects' factor and face set the within subjects' factor. A significant interaction was found between adaptation condition and face set ($F(1,62)=24.045$, $p=<0.001$, $\eta_p^2=0.279$). A significant main effect for adaptation condition was found ($F(1,62)=5.944$, $p=<0.018$, $\eta_p^2=0.087$). No main effect of face set was observed ($F(1,62)=0.208$, $p=0.650$) (see Figure 1).

Planned, paired t-tests were used to test for adaptation for each condition independently. For the expanded homogenous/contracted heterogeneous adaptation condition significant aftereffects were observed, with a significant difference between preference for diverse faces ($M=1.72$, $SD=5.34$), and homogenous faces ($M=-0.88$, $SD=4.89$), ($t(31)=-2.551$, $p=0.016$). For the contracted homogenous/expanded heterogeneous adaptation condition significant aftereffects were also observed, with a significant differences between preference for homogenous faces ($M=4.31$, $SD=4.25$) and diverse faces ($M=1.19$, $SD=3.09$), ($t(31)=5.47$, $p=<0.001$). Both conditions were consistent with adaptation (see Figure 1).

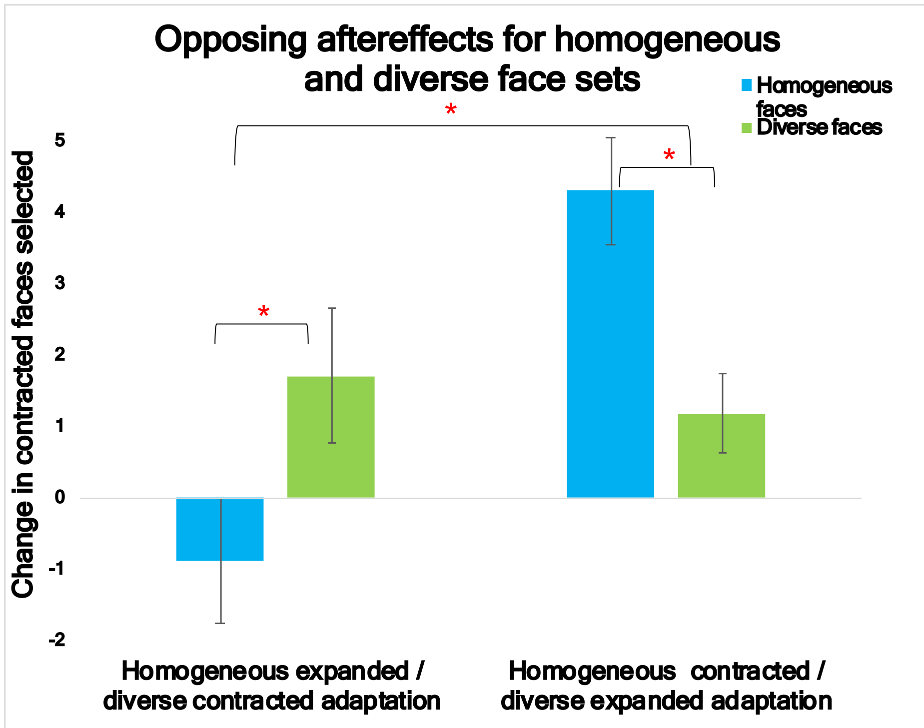



*Figure* 1. Mean change in contracted faces selected from pre to post adaptation for each condition. There were significant differences in the mean change in number of contracted faces selected for the homogenous and diverse faces selected for both adaptation conditions.

## 4. Discussion

The purpose of the current study was to test 1) whether a face set that is diverse with respect to race and gender could support a face aftereffect and 2) whether race and gender diversity is the kind of socially meaningful cue to category membership that is thought necessary for the creation of opposing aftereffects. Participants adapted to a homogenous face set consisting of only White middle-aged male faces and a diverse face set consisting of a balanced sample of White, Asian, Black, and Latino male and female face while the two faces sets were distorted in the opposite direction.

First, aftereffects were observed, including aftereffects produced by adaptation to the diverse face set. These results indicated that though there was a physical variation across the faces in the diverse face set, the adaptation phase of the experiment produced a coherent directional adaptation. This is the first indication that it is possible to adapt to a face set that has physical variation with respect to sex and gender.

Second, opposing aftereffects were found between the diverse and homogenous face sets. This is the first indication that the diversity of a face set might be the kind of socially meaningful cue to group membership that is necessary for the formation of opposing aftereffects. This is the first evidence that the diversity itself may be a cue to social category membership.

The diverse face set in the current study consisted of a balanced sample of 4 different races and both male and female faces. Typically, during opposing aftereffects paradigm, the physical variation within a face set only differs based on the individual's identities, while their race or gender is the same within the face set but different between the face sets (Armann et al., 2011; Jaquet, Rhodes, & Hayward, 2008; Little et al., 2008). Recent research on ensemble coding suggests that when perceiving groups of faces it is possible for individuals to extract uniquely social properties from groups of people, such as diversity and hierarchy even with minimal social cues (Phillips, Slepian, & Hughes, 2018). Not only does the current study suggest that the diversity of faces could be a cue to social category membership, but also that it is possible to adapt to a group of faces that vary physically in a number of ways.

The ability for individuals to have perceived the diverse face set as a group is remarkable considering how physically different the faces were. Zellmer-Bruhn, Maloney, Bhappu, and Salvador (2008) suggest that when a new group of faces is presented the most obvious social categories, such as sex, race, and ethnicity, will shape the perception of similarity and diversity within groups. The more distinct the faces are, the greater the possibility of viewing one group of faces based on multiple sub-categories face groups (Lau & Murnighan, 1998). However, when diverse identities are perceived in a more complex and integrated manner it is possible that the perceiver is more likely to perceive the group as one diverse whole rather than separate identities (Roccas & Brewer, 2002). It is possible that during adaptation the diverse face set may have facilitated a more complex perception of the diverse set, such that the diverse face set was viewed as a group, separate from the homogenous set.

The ability to adapt to multiple races and genders at the same time is also consistent with one previous study's findings that it is possible to adapt to the expression of a face set and the gender at the same time as one face set, using an opposing aftereffects paradigm (Bestelmeyer, Jones, DeBruine, Little, & Welling, 2010). The results from the current study expand on this phenomenon by exploring whether different races and sexes could also be adapted to as one face set. As opposing aftereffects were observed between the homogenous and diverse face set, it is possible that the diverse face set was adapted to as one group due to the ability to adapt to multiple different sexes and races independently in the same direction at once (Bestelmeyer et al., 2010; Bruce & Young, 1986) and perceiving the diverse group as one ensemble (Haberman & Whitney, 2009).

As this is the first evidence of adaptation to a face set that varies by both gender and race, there are multiple interpretations of how this affects the norm-based coding of these faces. First, it is possible that while adapting to the diverse face set, multiple face templates (4 races by 2 genders) were adapted to simultaneously as there are separate face templates by gender and race (Jaquet & Rhodes, 2008; Jaquet, Rhodes & Hayworth, 2008; Rhodes et al., 2004; Little, DeBruine, Jones, & Waitt, 2008). Under this interpretation, it is possible that when adapting to the diverse face sets each of the presented genders and races were adapted to in the same direction due to those specific templates all being adapted to at once.

Second, it is possible that a broader umbrella representation of all these faces underlies the perception of the entire face set, and that neural representation is what was adapted. Although aftereffects evidence indicates that there are multiple separate templates for differing genders and races, evidence on ensemble coding suggests that when the visual system is presented with several faces rather than coding every individual element presented it favours a summary or average (Haberman & Whitney, 2009). For example, when perceiving an ensemble of faces, participants are able to detect average facial morphology (de Fockert & Wolfenstein, 2009), emotional expression (Haberman, & Whitney, 2009; Won & Jiang, 2013), and attractiveness (Walker & Vul, 2014). Therefore, it is possible that a summary perception represents the diverse faces. Under this interpretation, an umbrella or average template may have facilitated the formation of aftereffects in the diverse face set.

The second hypothesis examined whether race and gender diversity are a socially meaningful cue to category membership. In order to evoke opposing aftereffects, it is thought that two face sets must be both physically distinct (Bestelmeyer et al., 2008) and socially meaningful (Short & Mondloch, 2010). In the current study, the opposing aftereffects speak to the psychological grouping that underlies category membership. The social significance of diversity was a relevant cue to social group membership that may support opposing aftereffects.

Diversity has been found to be a relevant social cue that can be extracted when viewing an ensemble of faces (Phillips, Slepian, & Hughes, 2018). In the United States, the Democratic party is increasingly more racially diverse than the Republican party (Newport, 2013), which results in diversity itself being a cue to party membership. The fact that opposing aftereffects were observed suggests that diversity was a socially meaningful cue that influenced category membership perception.

The result from the current study provides insight into the ability to adapt to a diverse face set as one coherent group. Future studies might test whether this finding generalized across other groupings of race and sex. For example, were the results of the current study unique to a homogenous face category that consisted of White middle-aged males? Would similar results occur between homogenous and diverse face sets if a minority group was chosen as the homogenous social category? It is possible that social hierarchy may play a role in determining which groups lack diversity. Perhaps changing the homogenous group to another race or sex would lead to null results. Further research is necessary in order to understand how diversity and social hierarchy impact visual adaptation to faces.

## 5. Conclusion

The purpose of this study was to test 1) whether adapting to a diverse face set could lead to a coherent aftereffect and 2) whether it is possible to adapt to a homogenous and a diverse face set simultaneously using an opposing aftereffect paradigm. Results revealed that opposing aftereffects were evoked for the homogenous and diverse face sets. These results suggest that it is possible to adapt to a set of faces that differs physically within the set based on sex and race while also adapting to another set that does not. This was the first evidence that diversity may be a cue to social group membership sufficient to support opposing aftereffects.

## 6. References

Armann, R., Jeffery, L., Calder, A. J., & Rhodes, G. (2011). Race-specific norms for coding face identity and a functional role for norms. *Journal of Vision*, *11*(13), 9–9. https://doi.org/10.1167/11.13.9

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. https://doi.org/10.1080/13506280802708024

Blakemore, C., & Sutton, P. (1969). Size adaptation: A new aftereffect. *Science*, *166*(3902), 245–247.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*(3), 305–327.

Clifford, C. W. (2002). Perceptual adaptation: Motion parallels orientation. *Trends in Cognitive Sciences*, *6*(3), 136–143.

Clifford, C. W. G., & Rhodes, G. (2005). *Fitting the Mind to the World: Adaptation and After-Effects in High-Level Vision*. OUP Oxford.

de Fockert, J., & Wolfenstein, C. (2009). Rapid extraction of mean identity from sets of faces. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 62,* 1716 –1722. http://dx.doi.org/10.1080/17470210902811249

Frisby, J. P. (1979). *Seeing: Illusion, brain and mind*. Oxford Univ. Press.

Gurnsey, R., Bryden, P. J., & Humphrey, G. K. (1994). An examination of colour-contingent pattern aftereffects. *Spatial Vision*, *8*(1), 77–94.

Haberman, J., & Whitney, D. (2009). Seeing the mean: ensemble coding for sets of faces. *Journal of Experimental Psychology: Human perception and performance,* 35(3), 718–734. https://doi.org/10.1037/a0013899

Jacobs, B. (2018, November 14). Photo of new House members shows big gap in diversity between parties. *The Guardian*. https://www.theguardian.com/us-news/2018/nov/14/congress-diversity-democrats-republicans-photo

Jaquet, E., & Rhodes, G. (2008). Face aftereffects indicate dissociable, but not distinct, coding of male and female faces. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(1), 101–112. https://doi.org/10.1037/0096-1523.34.1.101

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Lau, D. C., & Murnighan, J. K. (1998). Demographic diversity and faultlines: The compositional dynamics of organizational groups. *Academy of Management Review*, *23*(2), 325-340.

Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature Neuroscience*, *4*(1), 89–94. https://doi.org/10.1038/82947

Leopold, D. A., Rhodes, G., Müller, K.-M., & Jeffery, L. (2005). The dynamics of visual adaptation to faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1566), 897–904.

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, A.C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Manning, J. E. (n.d.). *Membership of the 116th Congress: A Profile*. 13.

Mather, G. E., Verstraten, F. E., & Anstis, S. E. (1998). *The motion aftereffect: A modern perspective.* The MIT Press.

Newport, F. (2013). Democrats Racially Diverse; Republicans Mostly White: Democrats and independents grow more diverse since 2008. Retrieved from https://news.gallup.com/poll/160373/democrats-racially-diverse-republicans-mostly-white.aspx

Phillips, L. T., Slepian, M. L., & Hughes, B. L. (2018). Perceiving groups: The people perception of diversity and hierarchy. *Journal of Personality and Social Psychology*, *114*(5), 766.

Roccas, S., & Brewer, M. B. (2002). Social identity complexity. Personality and Social Psychology Review, 6, 88–106.

Rhodes, G., & Jeffery, L. (2006). Adaptive norm-based coding of facial identity. *Vision Research*, *46*(18), 2977–2987.

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., & Nakayama, K. (2003). Fitting the mind to the World: Face Adaptation and Attractiveness Aftereffects. *Psychological Science*, *14*(6), 558–566. https://doi.org/10.1046/j.0956-7976.2003.psci_1465.x

Rhodes, G., Jeffery, L., Watson, T. L., Jaquet, E., Winkler, C., & Clifford, C. W. (2004). Orientation-contingent face aftereffects and implications for face-coding mechanisms. *Current Biology*, *14*(23), 2119–2123.

Rhodes, G., & Leopold, D. A. (2011). Adaptive norm-based coding of face identity. *The Oxford Handbook of Face Perception*, 263–286.

Short, L. A., & Mondloch, C. J. (2010). The Importance of Social Factors is a Matter of Perception. *Perception*, *39*(11), 1562–1564. https://doi.org/10.1068/p6758

Sutherland, N. S. (1961). Figural after-effects and apparent size. *Quarterly Journal of Experimental Psychology*, *13*(4), 222–228.

Suzuki, S. (2003). Attentional selection of overlapped shapes: A study using brief shape aftereffects. *Vision Research*, *43*(5), 549–561.

Thompson, P., & Latchford, G. (1986). Colour-contingent after-effects are really wavelength-contingent. *Nature*, *320*(6062), 525–526.

Walker, D., & Vul, E. (2014). Hierarchical encoding makes individuals in a group seem more attractive. Psychological Science, 25, 230 –235. http://dx.doi.org/10.1177 /0956797613497969

Watson, T. L., & Clifford, C. W. (2003). Pulling faces: An investigation of the face-distortion aftereffect. *Perception*, *32*(9), 1109–1116.

Webster, M. A. (2011). Adaptation and visual coding. *Journal of Vision*, *11*(5), 3–3. https://doi.org/10.1167/11.5.3

Webster, Michael A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature*, *428*(6982), 557. https://doi.org/10.1038/nature02420

Webster, Michael A., & Maclin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review*, *6*(4), 647–653. https://doi.org/10.3758/BF03212974

Won, B. Y., & Jiang, Y. V. (2013). Redundancy effects in the processing of emotional faces. *Vision Research, 78,* 6 –13. http://dx.doi.org/10 .1016/j.visres.2012.11.013

**Appendix A.** Names Demographic information of the Members of Congress used as stimuli

| Name | Race | Gender | Political Party | Phase |
|---|---|---|---|---|
| Ben Cline | White | Male | Republican | Adaptation |
| Bryan Steil | White | Male | Republican | Adaptation |
| Chris Smith | White | Male | Republican | Adaptation |
| Daniel Webster | White | Male | Republican | Adaptation |
| Drew Ferguson | White | Male | Republican | Adaptation |
| Jeff Fortenberry | White | Male | Republican | Adaptation |
| Jim Banks | White | Male | Republican | Adaptation |
| John Joyce | White | Male | Republican | Adaptation |
| Ken Buck | White | Male | Republican | Adaptation |
| Mark Meadows | White | Male | Republican | Adaptation |
| Rodney Davis | White | Male | Republican | Adaptation |
| Steve Womack | White | Male | Republican | Adaptation |
| Tim Burchett | White | Male | Republican | Adaptation |
| Tom Emmer | White | Male | Republican | Adaptation |
| Mac Thornberry | White | Male | Republican | Adaptation |
| Tom McClintock | White | Male | Republican | Adaptation |
| Joe Neguse | Black | Male | Democrat | Adaptation |
| John Lewis | Black | Male | Democrat | Adaptation |
| Karen Bass | Black | Female | Democrat | Adaptation |
| Val Demings | Black | Female | Democrat | Adaptation |
| Doris Matsui | Asian | Female | Democrat | Adaptation |
| Grace Meng | Asian | Female | Democrat | Adaptation |
| Mark Takano | Asian | Male | Democrat | Adaptation |
| Ted Lieu | Asian | Male | Democrat | Adaptation |

| | | | | |
|---|---|---|---|---|
| Jimmy Gomez | Latino | Male | Democrat | Adaptation |
| Linda Sanchez | Latino | Female | Democrat | Adaptation |
| Nanette Barragan | Latino | Female | Democrat | Adaptation |
| Raul Ruiz | Latino | Male | Democrat | Adaptation |
| David Trone | White | Male | Democrat | Adaptation |
| Ed Case | White | Male | Democrat | Adaptation |
| Sean Casten | White | Male | Democrat | Adaptation |
| Susan Wild | White | Female | Democrat | Adaptation |
| Alcee Hastings | Black | Male | Democrat | Pre & Post-Adaptation |
| Lisa Blunt Rochester | Black | Female | Democrat | Pre & Post-Adaptation |
| Stephanie Murphy | Asian | Female | Democrat | Pre & Post-Adaptation |
| TJ Cox | Asian | Male | Democrat | Pre & Post-Adaptation |
| Juan Vargas | Latino | Male | Democrat | Pre & Post-Adaptation |
| Norma Torres | Latino | Female | Democrat | Pre & Post-Adaptation |
| Cheri Bustos | White | Female | Democrat | Pre & Post-Adaptation |
| Scott Peters | White | Male | Democrat | Pre & Post-Adaptation |
| Brad Wenstrup | White | Male | Republican | Pre & Post-Adaptation |
| Bradley Byrne | White | Male | Republican | Pre & Post-Adaptation |
| James Comer | White | Male | Republican | Pre & Post-Adaptation |
| Jeff Duncan | White | Male | Republican | Pre & Post-Adaptation |
| Michael Guest | White | Male | Republican | Pre & Post-Adaptation |
| Ralph Abraham | White | Male | Republican | Pre & Post-Adaptation |
| Roger Marshall | White | Male | Republican | Pre & Post-Adaptation |
| Russ Fulcher | White | Male | Republican | Pre & Post-Adaptation |

## Chapter 5:

## Face aftereffects impact the perception of faces after a one-week delay

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### Preface

Opposing aftereffects paradigms consist of adapting to two separate categories of faces distorted in opposite directions (Bestelmeyer et al., 2008; Little et al., 2005). These paradigms are utilized to determine the existence of separable face norms for social categories. After adaptation, if attractiveness judgements shift in the direction of adaptation for both of the categories adapted to it is suggested that there must be two separate templates. This is predicted as opposing aftereffects indicate adaptation to two categories simultaneously in opposite directions and that separate templates that do not interfere with each other. Adults have previously been found to have separate face norms for several social categories (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Little et al., 2008; Schweinberger et al., 2010; Skinner & Benton, 2010).

Adaptation techniques have been utilized within the lab to explore the representation of adult's face space. Face norms are malleable and encompass the faces we see every day, allowing for our norms to be manipulated within the lab (Rhodes & Tremewan, 1996; Valentine et al., 2004). The decay of adaptation has previously been examined for various types of simple aftereffects. Simple aftereffects consist of only adapting to one direction or distortion of faces (Leopold et al., 2005; Rhodes et al., 2007). The decay of simple aftereffects has been found to vary based on the stimuli type with simple face aftereffects diminishing rapidly after adaptation (Leopold et al., 2005; Rhodes et al., 2007). However, other forms of aftereffects such as gaze (Kloth et al., 2017; Kloth & Rhodes, 2016; Kloth & Schweinberger, 2008) and colour adaptation (Neitz, Carroll, Yamauchi, Neitz, & Williams, 2002; Delahunt, Webster, Ma, & Werner, & 2004) have been found to persist much longer, up to days after adaptation.

The decay time course of opposing aftereffects paradigms has yet to be explored. The purpose of this chapter was to examine whether 7 days after initially adapting to an opposing aftereffects paradigm if participants still showed evidence of some influence of their week-old aftereffects. This question was examined through utilizing the religious opposing aftereffects paradigm for Christian and Muslim faces, only applying the conditions with religiously explicit audio. Participants adapted to one direction of a condition on their first session, and then were re-adapted and assessed 7-days later to the oppositely distorted condition.

Opposing aftereffects were observed for Christian and Muslim faces in session 1 but not session 2. The previous adaptation influenced the ability to adapt to a new adaptation condition a week later. The relationship between post-adaptation session 1 attractiveness selections and pre-adaptation session 2 suggested decay did not fully occur over 7 days. The implication of these results reveals important information about the persistence of adaptation during opposing aftereffects as well as the persistence of social-categorical face norms. The manipulation of face space in opposing aftereffects paradigms is different from other forms of face aftereffects. The social relevance and categorical adaptation may have influenced the persistence of aftereffects, uncovering novel information about the malleability of our face space.

## References

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. https://doi.org/10.1080/13506280802708024

Clifford, C. W. (2002). Perceptual adaptation: Motion parallels orientation. *Trends in Cognitive Sciences*, *6*(3), 136–143.

Gurnsey, R., Bryden, P. J., & Humphrey, G. K. (1994). An examination of colour-contingent pattern aftereffects. *Spatial Vision*, *8*(1), 77–94.

Kloth, N., Pugh, C., & Rhodes, G. (2017). The contributions of temporal delay and face exposure to the decay of gaze direction aftereffects. *Journal of Vision*, *17*(3), 5–5. https://doi.org/10.1167/17.3.5

Kloth, N., & Rhodes, G. (2016). Gaze direction aftereffects are surprisingly long-lasting. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(9), 1311.

Kloth, N., & Schweinberger, S. R. (2008). The temporal decay of eye gaze adaptation effects. *Journal of Vision*, *8*(11), 4–4. https://doi.org/10.1167/8.11.4

Leopold, D. A., Rhodes, G., Müller, K.-M., & Jeffery, L. (2005). The dynamics of visual adaptation to faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1566), 897–904. https://doi.org/10.1098/rspb.2004.3022

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Rhodes, G., Jeffery, L., Clifford, C. W., & Leopold, D. A. (2007). The timecourse of higher-level face aftereffects. *Vision Research*, *47*(17), 2291–2296.

Rhodes, G., & Tremewan, T. (1996). Averageness, Exaggeration, and Facial Attractiveness. *Psychological Science*, *7*(2), 105–110. JSTOR.

Schweinberger, S. R., Zäske, R., Walther, C., Golle, J., Kovács, G., & Wiese, H. (2010). Young without plastic surgery: Perceptual adaptation to the age of female and male faces. *Vision Research*, *50*(23), 2570–2576. https://doi.org/10.1016/j.visres.2010.08.017

Valentine, T., Darling, S., & Donnelly, M. (2004). Why are average faces attractive? The effect of view and averageness on the attractiveness of female faces. *Psychonomic Bulletin & Review*, *11*(3), 482–487. https://doi.org/10.3758/BF03196599

Watson, T. L., & Clifford, C. W. G. (2006). Orientation dependence of the orientation-contingent face aftereffect. *Vision Research*, *46*(20), 3422–3429. https://doi.org/10.1016/j.visres.2006.03.026

**Abstract**

Visual adaptation occurs after prolonged exposure to a stimulus. The duration of aftereffects differs across stimulus types. It is unknown how long opposing face aftereffects last. The current study investigates whether naïve undergraduate participants' adaptation to faces differs from that of participants who had adapted to faces 7 days previously. We also tested for the interference of 7-day old aftereffects on the ability to re-adapt to a new condition. In session 1, undergraduates made preference selections before and after adapting to distorted faces. Participants then returned 7 days later to re-assess the same faces. Participants were then adapted to the Christian and Muslim faces distorted in the opposite direction. Participants showed evidence of opposing aftereffects in session 1 but not session 2. Adaptation strength was stronger in session 1 than in session 2. Week-old aftereffects interfered with the creation of aftereffects in the opposite direction 7 days later.

***Keywords:*** *visual adaptation; aftereffects; opposing aftereffects; religion; adaptation decay*

## Introduction

Visual adaptation consists of distortion in perception following prolonged exposure to a stimulus (Clifford & Rhodes, 2005; Webster, 2011). This distortion is called an aftereffect. Adaptation involves a change in the perceptual system and causes reduced activity in the neurons responding to the adapting stimulus (Barlow & Hill, 1963; Bednar & Miikkulainen, 2000). The result is the perception of a neutral stimulus as the visual opposite of the fixated stimulus. For example, after viewing a line that is tilted in one direction, a vertical line will appear as if it is tilted in the opposite direction (Bednar & Miikkulainen, 2000; Gibson, 1933). After viewing a waterfall for several seconds, a nearby stationary rock will appear to move upwards (Barlow & Hill, 1963). Though aftereffects may be misperceptions, they have been frequently used as an experimental technique in understanding perception (see Clifford & Rhodes, 2005; Webster, 2011 for reviews).

**Simple aftereffects**

Simple aftereffects have been observed for a variety of visual properties such as colour (Gurnsey et al., 1994), motion (Clifford, 2002), contrast (Gibson, 1933), size ( Blakemore, Colin, & Sutton, 1969), texture (Durgin & Proffit, 1996), and shape (Suzuki, 2003). Aftereffects have been also observed in more complex visual stimuli, such as in faces. For example, face identity aftereffects have been observed when fixating on a face lead to an average face being perceived as differing from average in the opposite way (Rhodes & Jeffery, 2006).

Additionally, aftereffects have been observed for temporary aspects of the face, such as eye gaze direction (Jenkins, Beaver, & Calder, 2006) and emotional expression (Rutherford et al., 2008; Webster et al., 2004)

**Opposing aftereffects**

Opposing aftereffects occur when one category of distorted faces is adapted to, and simultaneously another face category which has been distorted in the opposite direction is also adapted to. For example, when observers adapt to contracted male faces and expanded female faces simultaneously. Opposing aftereffects paradigms are often used to test for discrete face templates that encode representations of different social categories of faces. If it is possible to adapt to both face categories in opposite directions, this then suggests that the neural coding for faces in one category is distinct from the neural coding of faces in the other category. Opposing face aftereffects have been observed in adults for race (Jaquet, Rhodes, & Hayward, 2008), gender (Jaquet et al., 2008; Little et al., 2005), age, and species (Little et al., 2008).

**Timecourse of aftereffects decay**

Simple configural face aftereffects (Leopold et al., 2005; Rhodes et al., 2007) and simple identity aftereffects (Rhodes et al., 2007) have shown a similar decay time course compared to simpler visual aftereffects such as tilt (Harris & Calvert, 1989), with decay diminishing within seconds after adaptation. However, colour aftereffects have been observed to persist weeks after adaptation (Neitz, Carroll, Yamauchi, Neitz, & Williams, 2002). Gaze aftereffects are found to be measurable several minutes after adaptation (Kloth, & Schweinberger, 2008), as well as up to 24 hours after adaptation (Kloth & Rhodes, 2016). Expression aftereffects have been estimated to fully decay within 9 hours after adaptation, (Burton et al., 2016) and identity aftereffects have been found to begin to decay as early as 300ms after adaptation (Leopold et al., 2005). These results suggest that the time course of decay may vary across the stimuli being adapted to.

The adaptation persistence of simple face aftereffects increases as a function of the length of adaptation duration and decreases within the test duration (Leopold et al., 2005; Rhodes et al., 2007). Rapid decay of aftereffects could be a challenge when trying to measure the adaptation during a test session that lasts several minutes. Therefore, some face adaptation paradigms include top-up adapting faces during post-adaptation test sessions to maintain the adaptation (Anzures et al., 2009; Rhodes et al., 2003).

**Current Study**

The current study was designed to test whether any persistent opposing aftereffects influence a subsequent adaptation session, and to test participants' ability to adapt to facial distortions in different directions 7-days after the initial face adaptation session. Religious opposing aftereffects were examined to explore the persistence or decay of opposing aftereffects to Christian and Muslim faces. Participants completed 2 sessions. In the first, they adapted to Christian and Muslim faces that had been distorted in opposite directions (contracted or expanded). Seven days later participants adapted to faces distorted in the opposite direction from what they saw in session 1, and adaptation was measured again. If the decay of the aftereffects occurs rapidly, then after 7 days participants should perform similarly to the naïve participants in session 1. However, if the adaptation persists for 7 days, effects from session 1 may interfere with the ability to adapt to session 2.

## Methods

### Photo Stimuli

Photographs of the faces of 30 self-identified Christian and 30 self-identified Muslim models were used in this experiment. The stimuli used were validated in a previous study (Foglia et al., 2021). Half of the models in each group were male, and half were female. Each original photo was expanded by +10 and +60 and compressed by -10 and -60 using the spherize function on Adobe Photoshop CS, yielding four manipulated images per model.

### Audio Stimuli

In the pre-adaptation phases, religious identity was cued using audio recordings that stated the model’s names, using names that are associated with a Muslim or Christian identity that were paired with each face. During the adaptation phases, three additional character description sentences were played. These sentences either indicated where the individuals practiced their faith, their favourite food, or what they were studying in school. All audio recordings were those used in Foglia et al. (2021).

### Participants

Thirty-six McMaster University students participated in this study. Two participants failed to complete both sessions and were therefore excluded from analyses. Analyses included 34 participants, (16 male; 18 female) ages ranged from 18-23 (*M*=18.6, *SD* =1.21). The sample size was selected to replicate the number of participants per adaptation group as in Foglia et al. (2021) in which opposing aftereffects for religion were first observed using an undergraduate sample. Participants received course credit for their time. Informed consent was obtained from all participants. Ethics permission was obtained from the McMaster University Research Ethics Board. All work was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Demographic information was obtained at the end of the second session (see Table 1).

**Table 1.** Participant's demographics and questionaries information

| | Participants (*N*= 34) |
|---|---|
| Country of birth | |
| Canada | 18 |
| China | 5 |
| Iran | 2 |
| Iraq | 1 |
| Nigeria | 1 |
| Palestine | 1 |
| Trinidad | 1 |
| Vietnam | 1 |
| Mexico | 1 |
| Bangladesh | 1 |
| Saudi Arabia | 1 |
| Egypt | 1 |
| Family's religious practice | |
| Catholic or Christian | 15 |
| None/Non-religious | 7 |
| Muslim | 7 |
| Hindu | 3 |
| Sikh | 1 |
| Buddhist | 1 |
| Own religious practice | |
| Catholic or Christian | 11 |
| None/Non-religious | 13 |
| Muslim | 6 |
| Hindu | 3 |
| Sikh | 1 |
| Frequency of religious practice (5 = highest) | |
| All participants | *M*= 2.29 |
| Christian | *M*= 2.18 |
| Muslim | *M*= 3.33 |
| Hindu | *M*=3.33 |
| Sikh | *M*= 4 |

**Procedure**

Participants were adapted in one of two adaptation session orders: They were either adapted to expanded Christian and contracted Muslim faces in the first session and contracted Christian and expanded Muslim in the second session or vice versa. All participants completed both adaptation conditions, with the 2 sessions scheduled 7 days apart. In each session, participants completed an identical procedure using a 15-inch ASUS laptop with the screen approximately 40 cm from the participant's face.

**Session 1 Procedure**

At the beginning of session 1, participants were given a description of the task followed by a consent form.

**Pre-adaptation.** Participants viewed 12 pairs of faces 4 times each in a randomized order. Each pair of images depicted the same model, with one face expanded by 10% and the other contracted by 10%, and participants were asked which of the two faces they found more attractive, in order to measure their baseline preference for contracted faces before adaptation. Six of the face pairs were Christian and 6 were Muslim. For each model, half of the time the expanded face was on the left, and the other half the right. An audio clip played along with each face pair, stating the name of the person depicted. Each pair was presented for 2 seconds, followed by a prompt screen instructing the participants to select via keypress which face they found more attractive.

**Adaptation.** In the adaptation phase participants fixated 60% distorted faces that were either contracted Christian and expanded Muslim faces or expanded Christian and contracted Muslim faces, depending on condition. Participants viewed 3 Christian faces and 3 Muslim faces, one at a time, 3 times each. Faces were presented in a randomized order for 7 seconds per face with a 500 millisecond inter-stimulus interval. Each face was paired with a character description audio clip.

**Post-adaptation.** The post-adaptation procedure was nearly identical to the pre-adaptation procedure. All face pairs were the same, and to maintain any adaptation, 6 top-up faces from the adaptation phase were presented for 1 second each in a randomized order, between the attractiveness ratings of the face pairs.

**Session 2 Procedure**

All participants returned to the lab for a second session 7 days after the first session. The experimental task was explained again, and participants completed a second consent form.

**Pre-adaptation.** Participants underwent the same pre-adaptation session procedure as they had completed 7 days prior.

**Adaptation.** The second session's adaptation phase was identical to the first session's adaptation phase, except that the direction of each participant's distortion was reversed, and the stimulus order was re-randomized.

**Post-adaptation.** After the second adaptation phase, participants underwent the same post-adaptation session procedure as they had completed 7 days prior.

**Demographic Questionnaires.** Upon completion of the experimental tasks of session 2, participants completed a questionnaire asking for their age, gender, country of birth, family's religious background, and the religion they practiced, if any. Participants were also asked to indicate how often they practiced their religion on a scale from 1 (never) to 5 (very frequently) (see Table 1). Finally, participants were debriefed.

## Results

### Adaptation to Distorted faces among Naïve Participants

To test whether face aftereffects were created in session 1, a 2 (adaptation condition: expanded Christian/ contracted Muslim or contracted Christian/ expanded Muslim faces) by 2 (religion: Christian or Muslim test face) repeated measures ANOVA was conducted using the number of trials in which a contracted face was preferred, measured post-adaptation during session 1. There was a significant interaction between adaptation condition and religion ($F(1, 32)=9.88$, $p=0.004$). There was no main effect of adaptation condition ($F(1, 32)=0.035$, $p=0.854$) or religion ($F(1, 32)=0.404$, $p=0.529$) (see Figure 1).

To test for opposing aftereffects, we conducted one-tailed paired *t*-tests for each adaptation condition separately. For the expanded Christian/ contracted Muslim adaptation condition, significant opposing aftereffects were observed

($t(17)=-3.11$, $p= 0.003$), with more preference for contracted Muslim faces (*M*= 19.22, *SD*=3.54), than contracted Christian faces (*M*=17.06, *SD*=4.34) as expected. For the Christian contracted/ Muslim expanded condition opposing aftereffects approached significance ($t(16)=1.54$, $p= 0.07$), with more preference for contracted Christian faces (*M*= 18.63, *SD*=3.81), than contracted Muslim faces (*M*=17.19, *SD*=5.21) as expected. Opposing aftereffects were created in session 1 among naïve participants (see Figure 1).

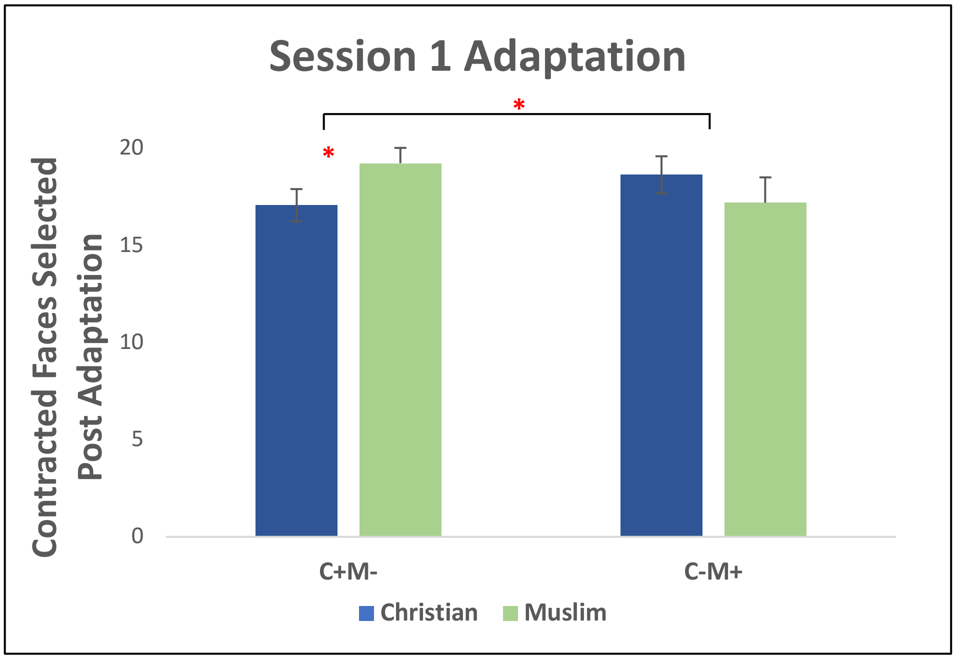



*Figure 1.*

*Figure 1.* Mean contracted faces selected post-adaptation during session 1 for the Christian expanded/ Muslim contracted (C+M-) and Christian contracted/ Muslim expanded (C-M+) adaptation conditions. Significant opposing aftereffects were observed for the Christian expanded/ Muslim contracted (C+M-) condition and approached significance for the Christian contracted/ Muslim expanded (C-M+) adaptation condition.

**Adaptation to Distorted faces among Experienced Participants**

Participants returned after 7 days and were adapted to the other adaptation condition: Those who had seen expanded Christian and contracted Muslim faces seven days earlier now saw contracted Christian and expanded Muslim faces and vice versa. Aftereffects were assessed to determine if participants were capable of re-adapting to a second condition in the opposite direction after a 7-day decay from the prior condition's direction.

A 2 (adaptation condition in session 2: expanded Christian/ contracted Muslim or contracted Christian/ expanded Muslim faces) by 2 (religion: Christian or Muslim test face) repeated measures ANOVA was conducted using the number of trials in which a contracted face was preferred, measured post-adaptation during session 2. No significant main effects were found for religion ($F(1, 32)=0.64$, $p=0.43$), for adaptation condition ($F(1, 32)=1.08$, $p=0.31$), nor was there an interaction between adaptation condition and religion ($F(1, 32)=0.79$, $p=0.38$) suggesting that 7 days after the original adaptation, opposing aftereffects in the opposite adaptation direction could not be created (see Figure 2).

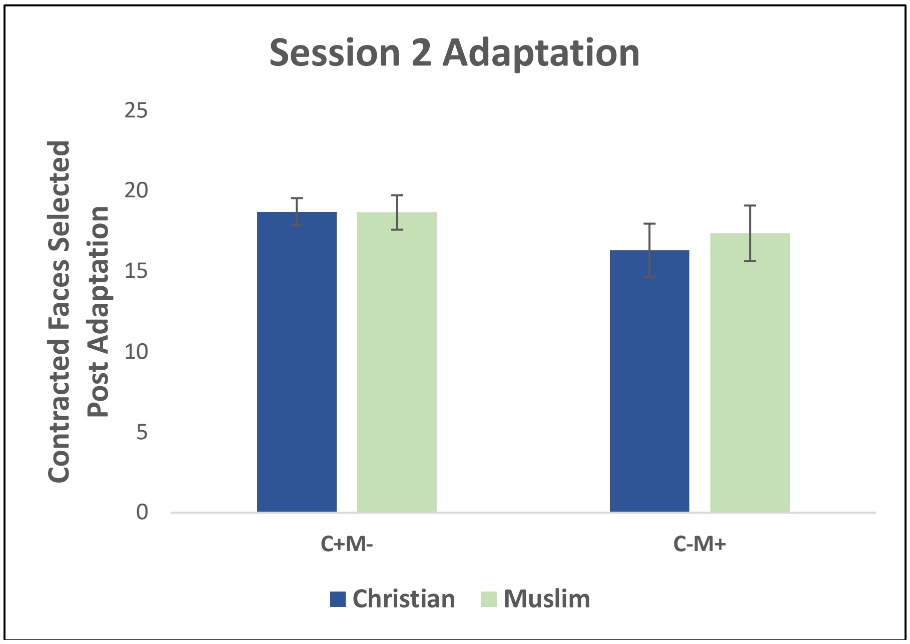



*Figure 2.*

*Figure 2.* Mean contracted faces selected post-adaptation session two for the Christian expanded/ Muslim contracted (C+M-) and Christian contracted/ Muslim expanded adaptation condition (C-M+). Opposing aftereffects were not observed.

**Adaptations were stronger in Session 1 than in Session 2**

To examine the strength of naïve participants' adaptation compared to their adaptation a week later as experienced participants, change scores were compared across sessions 1 and 2. Participant's change in preference for contracted faces scores was the difference in the number of contracted faces chosen before and after adaptation in each session, collapsed across the religious groups to get an overall adaptation strength.

A 2 (first adaptation condition) by 2 (session: session 1 or session 2) repeated measures ANOVA was conducted using participants' change scores as the dependent variable. A main effect of adaptation session time was observed ($F(1, 62)=12.12$, $p=0.001$). Participants adapted more strongly when they were naïve, in session 1 ($M=2.45$, $SD=3.78$) than they did when they were experienced, in session 2 ($M=0.55$, $SD=3.23$) (see Figure 3). There was no significant main effects of participant group ($F(1, 62)=0.76$, $p=0.39$) nor any interaction between participant group and adaptation session ($F(1, 62)=0.02$, $p=0.90$).

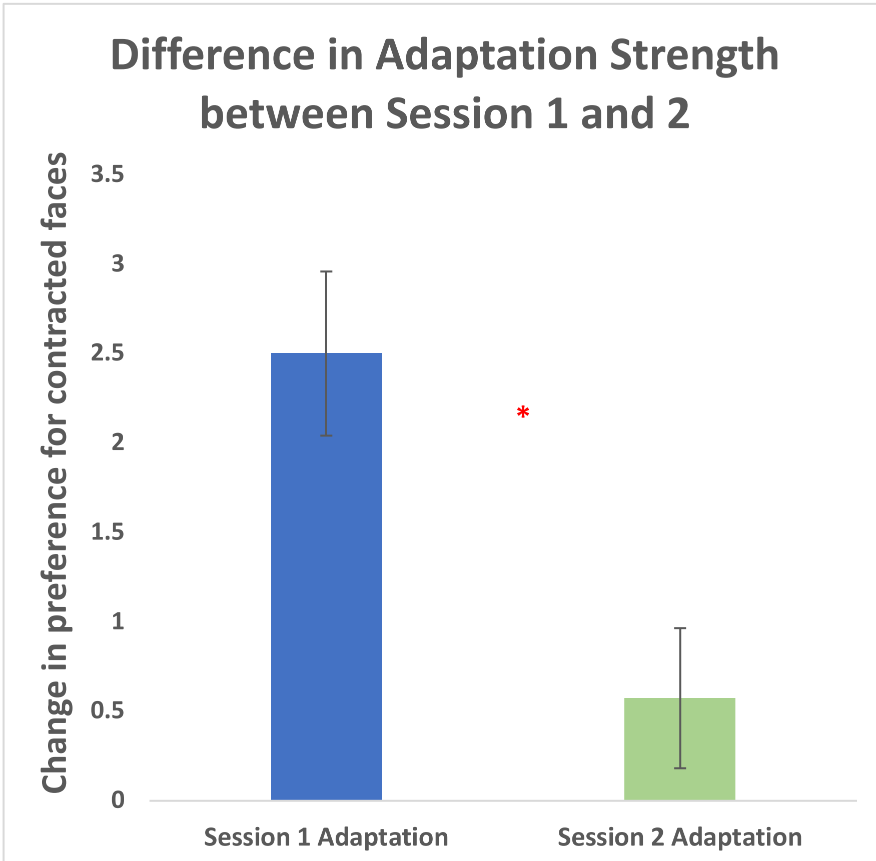



*Figure 3.*

*Figure 3.* Difference in change in preference for contracted faces from session 1 to session 2. Participants adapt significantly more in session 1 than in session 2.

**Adaptations were stronger in Session 1 than Session 2 after adapting to contracted faces**

Some research showing adaptation to distorted faces has reported different adaptation strengths to contracted versus expanded faces (Foglia et al. 2021). Therefore, we tested the strength of adaptation induced by fixating contracted faces and adaptation induced by fixating expanded faces separately across session 1 and session 2. The adaptation strength consisted of change scores from participants who adapted to Christian contracted faces in the first session combined with participants who adapted to Muslim contracted faces in the first session, while the converse was true for measures of adaptation to expanded faces.

A repeated measures ANOVA was conducted to compare responses contracted and expanded faces across sessions. There was more change in preference for contracted faces in session 1 ($M$= 3.12, $SD$=3.23) than session 2 ($M$= 0.26, $SD$=3.01) and this difference was significant ($F(1, 67)=14.22$, $p$=<0.001). However there was no significant difference in the change in preference for expanded faces between session 1 ($M$= 1.88, $SD$=4.25) and session 2 ($M$= 0.88, $SD$=3.45) ($F(1, 67)=1.14$, $p$=0.289) (see Figure 4). Therefore, adaptation to contracted faces but not expanded faces was interfered with 7 days after adapting to another condition.

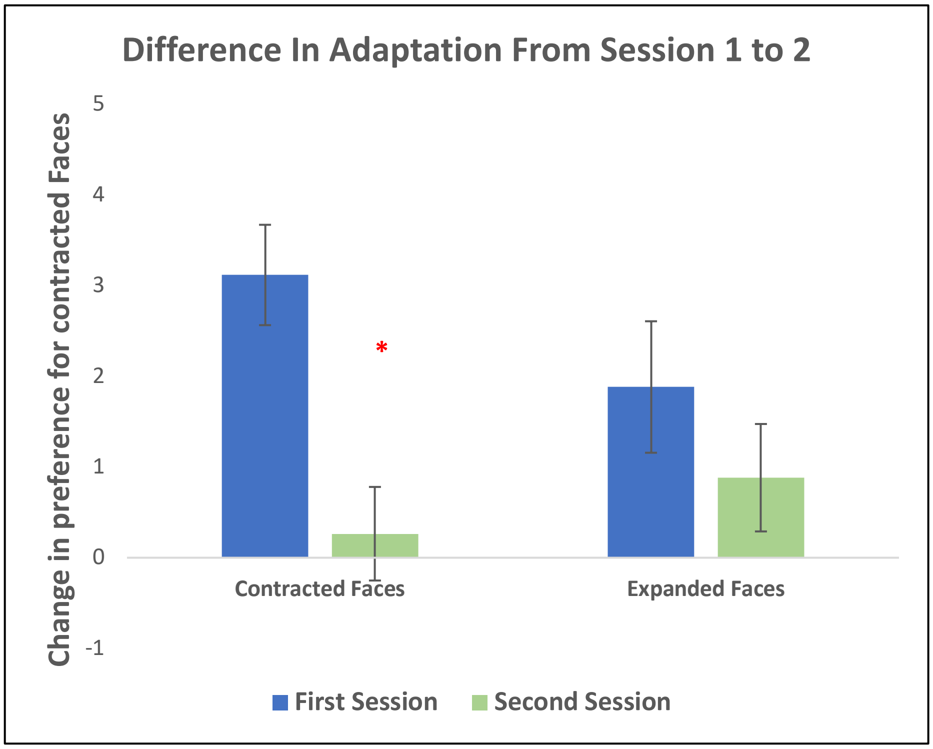



*Figure 4.*

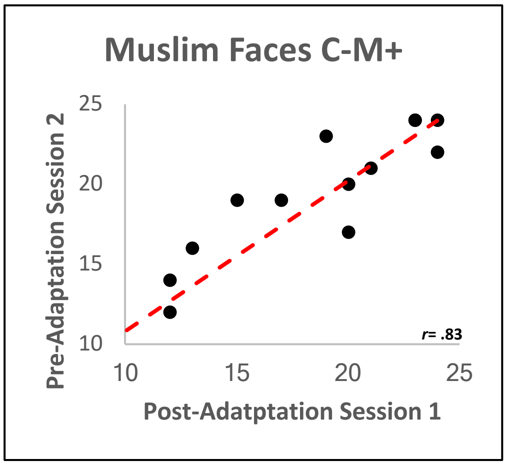
*Figure 4.* Change in preference for contracted faces for all contracted faces collapsed and expanded faces collapsed from session 1 to session 2. There is a significant difference in adapting in the expected direction to contracted faces from session 1 to session 2, but not expanded faces.

**Session 1 adaptation is measurable at the beginning of Session 2**

To test whether an individual's adaptation during session 1 influenced perception at the beginning of session 2, correlations were computed between the number of contracted faces selected post-adaptation session 1 and those selected seven days later at the beginning of session 2.

For participants who adapted to contracted Christian and expanded Muslim faces during their first session, a significant positive correlation was found between the number of contracted Muslim faces selected as more attractive during post-adaptation session 1 compared to pre-adaptation session 2 ($r(16)=0.834$, $p< 0.01$), two-tailed (see Figure 5A) and a significant positive correlation was found between the number of contracted Christian faces selected as more attractive during post-adaptation session 1 compared to pre-adaptation session 2 ($r(16)=0.762$, $p< 0.01$), two-tailed (see Figure 5B).

For those adapted to expanded Christian and contracted Muslim faces first, there was also a significant positive correlation between the number of contracted Muslim faces during post-adaptation session 1 and pre-adaptation session 2 ($r(18)=0.608$, $p< 0.01$), two-tailed (see Figure 5C). However, the correlation between the number of contracted Christian faces selected as more attractive when viewing pairs of Christian faces during post-adaptation session 1 compared to pre-adaptation session 2 was not statistically significant ($r(18)=0.212$ , $p=0.397$), two-tailed (see Figure 5D).



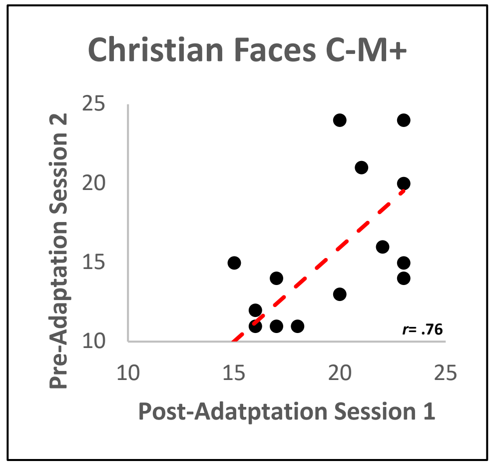
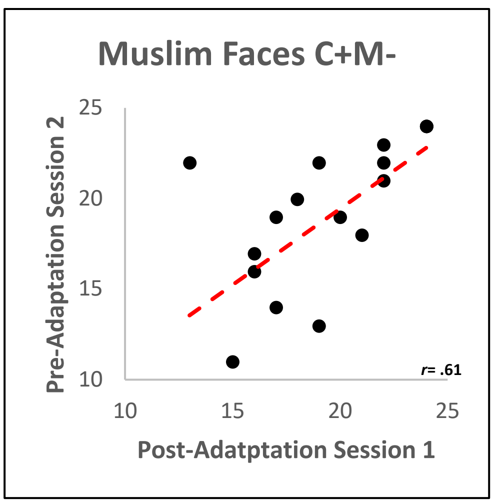




*Figure 5A.* *Figure 5B.*



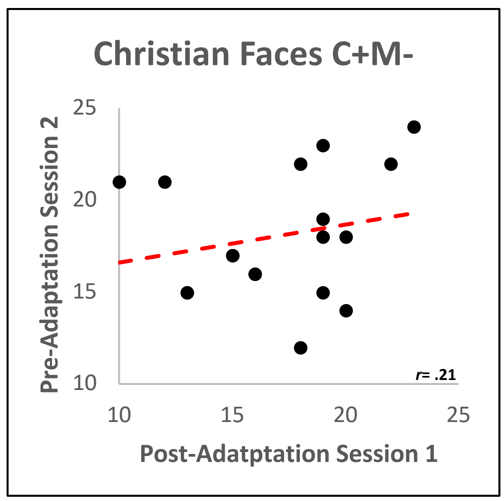




*Figure 5C.* *Figure 5D.*

*Figure 5.* Relationship between the post-adaptation session 1 attractiveness selections and pre-adaptation session 2 after 7 days for: *(5A)* Muslim faces in the Christian contracted/ Muslim expanded (C-M+) condition, *(5B)* Christian faces in the Christian contracted/ Muslim expanded condition (C-M+), (*5C)* Muslim faces in the Christian expanded/ Muslim contraction condition (C+M-), and (*5D*) Christian faces in the Christian expanded/ Muslim Contraction condition (C+M-).

## Discussion

The purpose of the current study was to test whether naïve participants' adaptation to faces differs from that of participants who had adapted to faces 7 days previously and whether experience with face adaptation interfered with an observer's ability to re-adapt to faces that were distorted in the opposite direction. Participants adapted to Christian and Muslim faces that were either contracted or expanded in session 1, and then returned to the lab a week later and re-evaluated the same faces. Although significant opposing aftereffects were observed in session 1, reversed opposing aftereffects were not evident in session 2, seven days later. Additionally, participants adapted more strongly in session 1 than in session 2, presumably because their previous adaptation interfered with subsequent adaptation. This interference suggests a week-long persistence of adaptation to contracted faces, just as colour aftereffects have also been found to persist weeks after adaptation (Neitz, Carroll, Yamauchi, Neitz, & Williams, 2002; Delahunt, Webster, Ma, & Werner, & 2004).

The significant relationship between face preferences during session 1 post-adaptation and preferences in session 2 pre-adaptation, 7 days later, suggests that adaptation induced during session 1 had not fully decayed. This is longer than the duration of face aftereffects that have been previously reported. Decay has been reported to begin immediately after adaptation to facial expressions (Burton et al., 2016), face identity (Leopold et al., 2005), and simple figural face aftereffects (Rhodes et al., 2007), with the length of decay depending on the length of fixation during adaptation. For example, Burton et al. (2016) has estimated that expression aftereffects would be extinct within hours of adaptation. Several other aftereffects also have been found to have a short time course (Harris & Calvert, 1989; Magnussen & Johnsen, 1986; Wolfe, 1984; Krauskopf, 1954). For example, contrast aftereffects that form after brief visual exposure begin to decay within seconds after adaptation, but adaptations resulting from longer fixation decay more slowly (Harris & Calvert, 1989). Tilt aftereffects decay within 30 minutes after adaptation (Magnussen & Johnsen, 1986). Previous face aftereffects paradigms exploring the decay of adaptation have used a simple aftereffect paradigm (Rhodes et al., 2007) whereas the current study used an opposing aftereffects paradigm, so it is possible that and the opposing adaptations may last longer than simple face adaptations.

Adaptation strength was found to be stronger in session 1, when participants were naïve than in session 2 when participants had previously adapted to distorted faces. Additionally, correlational analyses were conducted to test whether adaptation persisted from one session to the next. If all adaptation from session 1 decayed by session 2, the attractiveness selections from post-adaptation session 1, and the pre-adaptation session 2 after 7 days would not be expected to be related. However, attractiveness selections between post-adaptation session 1 selections and the pre-adaptation session 2 selections were correlated.

A reversal of the adaptation was not evident in session 2. When participants returned for session 2, they saw Christian and Muslim faces that had been manipulated in the opposite direction as the faces are seen 7 days prior. Opposing aftereffects did not occur after this second adaptation, indicating that the adaptation from session 1 not only persisted 7 days later but interfered with the ability to adapt in the opposite direction. Previously opposing aftereffects for Christian and Muslim faces have been observed in naive participants both here and in previous research (Foglia et al., 2021). Therefore, adapting to a previous condition interfered with the ability to re-adapt to the same faces 7 days later.

**Limitations and Future Directions**

The current study revealed that there was interference in re-adapting to contracted faces 7 days after the first adaptation but leaves open the question of how long opposing aftereffects ultimately last. Future studies could re-test participants at multiple time points, as well as compare simple versus opposing adaptation decay to determine how long simple and opposing face aftereffects last.

Additionally, whether the effects of the current study were modulated by the social category observed could be further examined. Opposing aftereffects have previously been observed for several other social categories, such as sex and race (Jaquet et al., 2008; Little et al., 2005; Little et al., 2008). As time decay for aftereffects varies based on the stimuli presented (Burton et al., 2016; Harris & Calvert, 1989; Kloth & Rhodes, 2016; Kloth & Schweinberger, 2008; Magnussen & Johnsen, 1986; Neitz et al., 2002), opposing aftereffects decays across other social categories should not be assumed. Future studies could test for the persistence of opposing aftereffects across categories defined by age and sex to examine the length of persistence and if there are differences based on the direction of the face.

**Conclusion**

The purpose of the current study was to explore whether naïve participants' adaptation to Christian and Muslim faces differs from that of participants who had adapted to faces 7 days previously and whether the persistence of previous aftereffects interferes with the creation of aftereffects in the opposite direction. The first adaptation session impacted participants' ability to adapt during the second session. Seven days after the first adaptation, participants were unable to re-adapt to faces distorted in the opposite direction. The persistence of week-old aftereffects interfered with the creation of aftereffects in the opposite direction 7 days later.

## References

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face Adaptation and Attractiveness Aftereffects in 8-Year-Olds and Adults. *Child Development*, *80*(1), 178–191.

Barlow, H. B., & Hill, R. M. (1963). Evidence for a physiological explanation of the waterfall phenomenon and figural after-effects. *Nature*, *200*(4913), 1345–1347.

Bednar, J. A., & Miikkulainen, R. (2000). Tilt Aftereffects in a Self-Organizing Model of the Primary Visual Cortex. *Neural Computation*, *12*(7), 1721–1740. https://doi.org/10.1162/089976600300015321

Blakemore, Colin, & Sutton, P. (1969). Size adaptation: A new aftereffect. *Science*, *166*(3902), 245–247.

Burton, N., Jeffery, L., Bonner, J., & Rhodes, G. (2016). The timecourse of expression aftereffects. *Journal of Vision*, *16*(15), 1–1.

Clifford, C. W. (2002). Perceptual adaptation: Motion parallels orientation. *Trends in Cognitive Sciences*, *6*(3), 136–143.

Clifford, C. W. G., & Rhodes, G. (2005). *Fitting the Mind to the World: Adaptation and After-Effects in High-Level Vision*. OUP Oxford.

Delahunt, P. B., Webster, M. A., Ma, L., & Werner, J. S. (2004). Long-term renormalization of chromatic mechanisms following cataract surgery. *Visual Neuroscience*, *21*(3), 301–307.

Durgin, F. H., & Proffit, D. R. (1996). Visual learning in the perception of texture: Simple and contingent aftereffects of texture density. *Spatial Vision*, *9*(4), 423–474.

Foglia, V., Mueller, A., & Rutherford, M.D. (2021). An explicit religious label impacts visual adaptation to Christian and Muslim faces. *Religion, Brain & Behavior.*

Gibson, J. J. (1933). Adaptation, after-effect and contrast in the perception of curved lines. *Journal of Experimental Psychology*, *16*(1), 1.

Gurnsey, R., Bryden, P. J., & Humphrey, G. K. (1994). An examination of colour-contingent pattern aftereffects. *Spatial Vision*, *8*(1), 77–94.

Harris, J. P., & Calvert, J. E. (1989). Contrast, spatial frequency and test duration effects on the tilt aftereffect: Implications for underlying mechanisms. *Vision Research*, *29*(1), 129–135.

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Jenkins, R., Beaver, J. D., & Calder, A. J. (2006). I thought you were looking at me: Direction-specific aftereffects in gaze perception. *Psychological Science*, *17*(6), 506–513.

Kloth, N., & Rhodes, G. (2016). Gaze direction aftereffects are surprisingly long-lasting. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(9), 1311.

Kloth, N., & Schweinberger, S. R. (2008). The temporal decay of eye gaze adaptation effects. *Journal of Vision*, *8*(11), 4–4. https://doi.org/10.1167/8.11.4

Krauskopf, J. (1954). The magnitude of figural after-effects as a function of the duration of the test-period. *The American Journal of Psychology*, *67*(4), 684–690.

Leopold, D. A., Rhodes, G., Müller, K.-M., & Jeffery, L. (2005). The dynamics of visual adaptation to faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1566), 897–904. https://doi.org/10.1098/rspb.2004.3022

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Magnussen, S., & Johnsen, T. (1986). Temporal aspects of spatial adaptation. A study of the tilt aftereffect. *Vision Research*, *26*(4), 661–672.

Neitz, J., Carroll, J., Yamauchi, Y., Neitz, M., & Williams, D. R. (2002). Color perception is mediated by a plastic neural mechanism that is adjustable in adults. *Neuron*, *35*(4), 783–792.

Rhodes, G., & Jeffery, L. (2006). Adaptive norm-based coding of facial identity. *Vision Research*, *46*(18), 2977–2987.

Rhodes, G., Jeffery, L., Clifford, C. W., & Leopold, D. A. (2007). The timecourse of higher-level face aftereffects. *Vision Research*, *47*(17), 2291–2296.

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., & Nakayama, K. (2003). Fitting the Mind to the World: Face Adaptation and Attractiveness Aftereffects. *Psychological Science*, *14*(6), 558–566.

Harris, J. P., & Calvert, J. E. (1989). Contrast, spatial frequency and test duration effects on the tilt aftereffect: Implications for underlying mechanisms. *Vision Research*, *29*(1), 129–135.

Kloth, N., & Rhodes, G. (2016). Gaze direction aftereffects are surprisingly long-lasting. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(9), 1311.

Kloth, N., & Schweinberger, S. R. (2008). The temporal decay of eye gaze adaptation effects. *Journal of Vision*, *8*(11), 4–4. https://doi.org/10.1167/8.11.4

Magnussen, S., & Johnsen, T. (1986). Temporal aspects of spatial adaptation. A study of the tilt aftereffect. *Vision Research*, *26*(4), 661–672.

Neitz, J., Carroll, J., Yamauchi, Y., Neitz, M., & Williams, D. R. (2002). Color Perception Is Mediated by a Plastic Neural Mechanism that Is Adjustable in Adults. *Neuron*, *35*(4), 783–792. https://doi.org/10.1016/S0896-6273(02)00818-8

Rutherford, M. D., Chattha, H. M., & Krysko, K. M. (2008). The use of aftereffects in the study of relationships among emotion categories. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(1), 27–40. https://doi.org/10.1037/0096-1523.34.1.27

Suzuki, S. (2003). Attentional selection of overlapped shapes: A study using brief shape aftereffects. *Vision Research*, *43*(5), 549–561.

Webster, M. A. (2011). Adaptation and visual coding. *Journal of Vision*, *11*(5), 3–3. https://doi.org/10.1167/11.5.3

Webster, M. A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature*, *428*(6982), 557. https://doi.org/10.1038/nature02420

Webster, M.A., & MacLeod, D. I. (2011). Visual adaptation and face perception. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1571), 1702–1725.

Wolfe, J. M. (1984). Short test flashes produce large tilt aftereffects. *Vision Research*, *24*(12), 1959–1964.

# Chapter 6: General Discussion

Much of adult's expertise with face perception has been explored through the lens of norm-based coding. Valentine's (1991) model of norm-based coding has led to several advancements in understanding how faces are represented cognitively in our "face space". More recently norm-based coding has been explored through a multi-norm lens (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Little et al., 2008; Schweinberger et al., 2010; Watson & Clifford, 2006). From this perspective, the existence of social categorical face norms has been supported and explored in both adults and children. Through manipulating and examining norm-based coding, it is possible to further investigate how our face space refines. There are still many gaps within the literature as to how children rely on norm-based coding, and how malleable adults' categorical face norms are. The current series of studies aimed to discover new information on adults' and children's reliance, development, representation, and malleability of their face space, via a norm-based perspective. By exploring responses to viewing distorted face stimuli it was possible to infer new information about adults' and children's face space.

## Summary and contributions

Chapter 2 investigated children's reliance on norm-based emotion perception strategies and how it develops from 6-15 years of age. Though children have shown evidence of norm-based coding via aftereffects paradigms as early as 4 years of age (Jeffery et al., 2010, 2013b; Short et al., 2011), several studies have shown that children's reliance on norm-based coding is immature compared to adults (Anzures et al., 2009; Nishimura et al., 2009; Short et al., 2011; 2014). This chapter utilized an exaggerated expression paradigm to test for reliance on norm-based emotion perception strategies (Rutherford & McIntosh, 2007; Walsh et al., 2014). Children were asked to choose which of 2 faces looks the most like a realistic representation of an emotion. A norm-based view predicts that extremely exaggerated facial expressions should not be a realistic representation of an emotion as our face-norms are based on the faces we encounter (Valentine, 1991).

The results of both experiments in chapter 2 demonstrated that children's reliance on norm-based emotion perception is a skill that is slowly developing throughout childhood into adolescence. In experiment 1 the relationship between age and tolerance for exaggeration demonstrated that younger participants selected more exaggerated emotions as realistic representations of happiness and sadness and that this tendency decreased with age. The purpose of experiment 2 was to re-examine this question with each of the basic emotions to determine if the same developmental pattern exists across all emotions. Experiment 2 replicated the same pattern for happy, sad, anger, fear, surprise, and disgust. Younger children showed less reliance on a norm-based emotion perception strategy as they are more likely to select the more exaggerated expressions than older children, with this behaviour decreasing with age. Together these experiments further contributed to our understanding of how children's reliance on norm-based emotion perception develops. It is evident through this chapter that children's reliance on norm-based coding for emotion perception is a skill that takes a considerable amount of time to develop. This chapter advanced the theoretical knowledge on children's reliance on norm-based coding by discovering a developmental timeline that had not been explored before.

In Chapter 3 we examined whether there are separate norm-based templates for Christian and Muslim faces in adults and 8-year-old children using opposing aftereffects paradigms. This chapter explored whether religion can be represented by face norms and whether we can manipulate the social relevance of face stimuli during adaptation. It has been shown that to evoke opposing aftereffects, faces categories must be both perceptually distinct (Short & Mondloch, 2010) and socially significant (Bestelmeyer et al., 2008; Jaquet et al., 2007). This chapter manipulated and controlled for these requirements in a novel way to explore whether religion is a social category that can evoke opposing aftereffects.

Experiment 1 first validated that the Christian and Muslim face sets appear physically distinctive. Experiment 2 utilized a new methodology to manipulate social meaning, presenting social categorical information via audio cues during adaptation. Separate religious-based face templates were observed for adults who adapted to the Christian and Muslim faces with the religious-explicit audio, but not those without. In experiment 3, eight-year-old children did not demonstrate similar religious aftereffects after adapting to a child-friendly paradigm (Anzures et al., 2009; Short et al., 2011).

Our novel methodology manipulating social significance highlights two important findings: 1) religious social categories can be represented like race (Bestelmeyer et al., 2010; Jaquet et al., 2008; Little et al., 2008) and sex in face space (Bestelmeyer et al., 2008, 2010; Little et al., 2005; Little et al., 2008; Schweinberger et al., 2010; Watson & Clifford, 2006), and 2) that our face space is experience-dependent and highly influenced based on how socially relevant different face categories are to us. These experiments advanced important new information on the development and representation of norm-based coding in adults and children. This chapter further demonstrated the developing refinement of children's face space, and that religious-contingent face templates may not be relevant enough to be present in the 8-year-old children we examined. Finally, this chapter revealed a new face category that can be represented in adult's face space, religion.

Chapter 4 explored two new questions about norm-based coding and social categorical adaptation. First, we examined whether it is possible to adapt to a face set that varies vastly across several dimensions. Typically during opposing aftereffects paradigms face sets are often controlled to vary along only one dimension, for example, all females are of the same race (Bestelmeyer et al., 2008; Little et al., 2005). We were interested in whether it was possible to adapt participants to a face set that varied based on race and sex. Our second question was whether diversity was a social category that could evoke opposing aftereffects and be perceived as a separate category than non-diverse faces.

Adults underwent an opposing aftereffects paradigm that consisted of adapting to a diverse face set (male, female, White, Black, Latinx, and Asian faces) and a homogenous face set (only White males). Results reveal opposing aftereffects between diverse and homogenous social categories. These results uncover interesting information about norm-based coding and our face space that has yet to be explored. For one, it is possible to adapt individuals to a face category that varied along several dimensions, a finding that will be beneficial for those who commonly utilize face adaptation techniques. Secondly, we demonstrated another new social categorical set of faces that can be manipulated in face space. The diverse group of faces was observed as perceptually district from homogenous White males, with diversity as the socially relevant cue to group membership. This finding unveils new information about how our face space represents groups of faces that vary physically, an area that had yet to be explored in opposing aftereffects, and rich in new possibilities to examine.

Finally, chapter 5 explored the persistence of adaptation after an opposing aftereffects paradigm, a decay timespan that had not previously been explored. Several face aftereffects have shown to decay quite rapidly, with simple configural face aftereffects (Leopold et al., 2005; Rhodes et al., 2007) and simple identity aftereffects (Rhodes et al., 2007) decay diminishing quickly after adaptation. However, other forms of aftereffects such as gaze direction (Kloth et al., 2017; Kloth & Rhodes, 2016; Kloth & Schweinberger, 2008) and colour (Neitz, Carroll, Yamauchi, Neitz, & Williams, 2002; Delahunt, Webster, Ma, &

Werner, & 2004) have been found to persist several hours to days after adaptation. All previous exploration of adaptation decay has focused on only simple or single category face adaptation. How adaptation decay could be influenced by categorical adaptation via opposing aftereffects paradigms or social relevance had yet to be explored.

Participants adapted to the religious explicit conditions from chapter 3, twice, with 7 days between the two sessions. The results of chapter 5 revealed a slow decay time course for religious aftereffects. Seven days after initially adapting to Christian and Muslim faces participants still showed evidence of some influence of their week-old aftereffects. The previous adaptation influenced the ability to adapt to a new condition a week later. These results suggested that the manipulation of face space in opposing aftereffects paradigms is different from simple face aftereffects. It is possible that the opposing aftereffect paradigm, the induced social relevance, or both influenced the persistence of aftereffects. This chapter contributed to the field by uncovering valuable new information about the malleable nature of our face space and how it modifies when presented with social categorical faces during adaptation.

Collectively these empirical chapters expand knowledge on the reliance, development, representation, and malleability of face templates in adults and children. Children's reliance on norm-based coding for emotion perception was a skill that slowly refines into adolescence. Religion and diversity were two new categories that can be represented by separate face templates for adults. Social relevance could be manipulated during adaptation through audio cues. Finally, manipulating face templates via opposing aftereffects paradigms persisted longer than other forms of face adaptation.

## Theoretical connections

### *Children's developing face space*

One of the major contributions of this dissertation is evidence for children's developing norm-based coding abilities. Under the exaggerated expression paradigm, previously it was found that adults with autism spectrum disorder (ASD) selected more exaggerated faces in comparison to typically developing adults (Walsh et al. 2014). From the results of Walsh et al. (2014), it is possible to infer that typically developed adults are using a norm-based strategy during the emotion perception task. Adults rejected overly exaggerated expressions as a realistic representation of an emotion. However, the results of chapter 2 indicate that though adults have this norm-based skill for emotion perception it is one that was gradually developing throughout childhood into adolescence. In both experiments 1 and 2, the negative relationship between age and tolerance for exaggeration indicated that 6-year-old children do not appear to be using this adult-like norm-based emotion perception skill. This norm-based skill is one that is refined with age over a long developmental span. These results support that children's face space is developing in refinement and reliance on norm-based coding. This chapter revealed new information about the developmental trajectory of these adult-like face perception skills.

The results of chapter 3 further explore children's norm-based coding through the use of an opposing aftereffects paradigm. Previously 8-year-olds were found to have separate categorical face templates for race (Short et al., 2011). In contrast, when examining 5-year-olds under several differing conditions similar results were not observed for race, sex, or age (Short et al., 2011; 2014). In chapter 3 opposing aftereffects for religion were not observed in 8-year-olds, even though they were in adults. Previously, Short et. al (2011) proposed two theories as to why race-contingent face-norms may not be observed in younger children, and these theories apply well for other social categorical information like religion. One possibility is that children may possess separate face templates, but their own social-categorical template may be stronger than their other-social categorical template. As several of the children were Caucasian and Christian in chapter 3, it is possible that their own-Christian religion template was more refined than their other-Muslim template. The other possibility is that children's other face template has not yet emerged at all. Therefore, the Christian children may not have a Muslim-specific face template yet. The results from chapter 3 connect to and advance the previous theoretical hypotheses on children's face templates. This is further discussed in the following subsection on social significance.

Together chapters 2 and chapter 3 explore children's refinement and reliance on norm-based coding through two separate paradigms. While the paradigms may differ, they both come to similar conclusions: norm-based coding is an adult-like face perception skill that children are developing. Though chapter

3 does not examine religious-based face templates developmentally, opposing aftereffects were observed in adults in experiment 2 but not in children in experiment 3. Chapter 2 highlighted that children's reliance on norm-based coding for emotion perception is developing into adolescence. While children do show evidence of some norm-based coding skills as young as 4-years-old (Jeffery et al., 2013a), like several other face perception tasks (Carey et al., 1980; Carey, 1992; Gao & Maurer, 2009; Mondloch et al., 2002; 2003), norm-based coding in children was found to improve into childhood. The results from this dissertation advance the theoretical knowledge on children's reliance on norm-based coding and their developing face space. The implications from these studies suggest that some of the immaturity children have with face perception can be attributed to their developing norm-based coding skills.

***Social relevance and norm-based coding***

A second major contribution this dissertation has on the field of norm-based coding is highlighting the effects of social relevance on face space. Chapter 3 revealed a novel methodology for manipulating the social relevance of face stimuli during adaptation. Previously social relevance has been examined by manipulating the physical distance between like-category face groups compared to separate-category face groups on adaptation, revealing that categories must be socially relevant to evoke opposing aftereffects (Bestelmeyer et al., 2008; Jaquet et al., 2007). Short and Mondloch (2010) also previously manipulated social significance via artificial in groups and out groups, though this social category was not relevant enough alone without physical distinctiveness to evoke opposing aftereffects. My dissertation reveals a new technique that can be utilized to evoke social meaning during adaptation: audio information.

When presenting social categorical audio cues in chapter 3, differences were observed for the ability to adapt to Christian and Muslim faces. In experiment 2, half of the participants adapted to Christian and Muslim distorted faces with religiously explicit audio clips, the other half of participants heard religiously irrelevant control audio. With the physical similarity of the faces being controlled for, opposing aftereffects were only observed in the religious explicit audio condition. This finding revealed important contributions to norm-based coding. For one, our face templates are organized around how relevant categories of faces are to us, further supporting previous findings on this requirement for opposing aftereffects adaptation (Bestelmeyer et al., 2008; Jaquet et al., 2007). Secondly, as we are unaware how relevant some face categories are to participants before they enter the lab, this chapter demonstrated that we could manipulate social relevance within the lab via audio clips. This chapter advanced the knowledge on the effects of social significance on face space and provides a novel method to manipulate this in the lab. This methodology allows for further exploring the experience-dependent and malleable nature of our face space in adults and children.

Experiment 3 of chapter 3 also contributed to understanding the importance of social meaning on norm-based coding. Though adults show evidence of religious opposing aftereffects, 8-year-olds do not. Some reasons why children did not adapt accordingly could be related to how socially relevant these categories were. For one, the child paradigm did not utilize the same religious explicit audio as in experiment 2. Children were adapted with a different child-friendly paradigm (Anzures et al., 2009; Short et al., 2011) and it is possible that the social categorical relevance of the characters was not as strongly induced. Children were told in the storybook adaptation that the characters within were either Christian or Muslim and given social categorical information about them. Though after introduced, other than the character's religious-based names their religion is not repeated verbally on every page. As children have been found to need stronger stimuli distortions to evoke aftereffects (Anzures et al., 2009; Short et al., 2011) it is possible that when manipulating social relevance they also may need more information than adults, or at least the same type of manipulation to see similar effects. Secondly, the majority of the children in experiment 3 were Caucasian, Christian, and not highly religious. This demographic information could also affect how socially relevant the children perceived Christian and Muslim as social categories, resulting in a lack of opposing aftereffects. The results from this chapter advanced the implications as to how the social significance of face categories affected children's and adult's refinement in face space.

Chapters 3 and 4 also contribute novel information about social significance during adaptation. Chapter 3 examines whether diverse faces could be perceived as a separate category from homogenous White male faces. This chapter did not provide audio information to induce category membership, participants only viewed contracted and distorted diverse and homogenous faces continuously during adaptation. Even though White males' faces were in both face categories, the diversity was physically distinct enough to be perceived as a separate category. The main categorical information manipulated in this chapter was diversity. Therefore, the implications of this chapter revealed that diversity can be considered a socially relevant category cue to adaptation, a novel finding about the representation of adult's face space.

Finally, chapter 4 examined the persistence of adaptation to opposing aftereffects paradigms, specifically when social categorical significance is heightened. Previously all examination of aftereffects decay has been observed only for single category adaptation (Leopold et al., 2005; Rhodes et al., 2007). The results of chapter 4 revealed that religious opposing aftereffects adapted to with religious explicit audio are still evident several days after adaptation. This could be related to the influence of audio cues during adaptation. It is possible that enhancing the social significance of the faces during adaptation resulted in a longer decay time than other adaptation paradigms. Whether it is the opposing adaptation paradigm, the audio recordings, or both, chapter 5 highlights new theoretical advancements on the effects of social significance. Relevant social categorical adaptation may persist much longer than other forms of adaptation.

The implications of these results contribute to new information about the manipulation, persistence, and malleability of adult's face space.

Therefore chapters 3 through 5 all reveal new information and implications as to how social relevance affects the organization, representation, and manipulation of face space through opposing aftereffects paradigms. These chapters manipulated new aspects that had yet to be explored about social categorical face templates. Chapter 3 highlighted that social significance can be manipulated within the lab via audio cues. Chapters 3 and 4 emphasized new socially relevant categories that can be represented in face space. Chapter 5 emphasized that social relevance affects the persistence of adaptation. This empirical work greatly advances the theory representing how social significance affects norm-based coding and face templates.

**Limitations**

One limitation of chapter 2 is the visible differences across the stimulus distortions in experiment 1 and experiment 2. In experiment 1 the Happy and Sad distorted continuum was from Walsh et al. (2014). However, the creation of experiment 2 required a new set of stimuli consisting of each of the basic emotions. The stimuli distortion continuum in experiment 1 may have appeared more extreme than the experiment 2 due to two reasons: 1) the stimuli were created using WebMorph, a web-based and newer version of the PsychoMorph software package that had changed and improved over time (DeBruine, 2018), and 2) the photographs were created using validated stimulus set to keep the models consistent across all emotions (Tottenham et al., 2009). Though a similar pattern of results emerges across experiments 1 and 2 the visible differences in distortions should be considered as this is a norm-based task. Through a norm-based view, more distorted stimuli are expected to result in differences in behavioural responses compared to less distorted stimuli (Jeffery et al., 2010; Loffler et al., 2005; Rhodes et al., 2005; Robbins et al., 2007). Therefore, it is possible that perceivably less extreme distortions could have some effect on the selection of more exaggerated faces in experiment 2 and should be considered when making comparisons between the two experiments.

Chapters 3-5 revealed interesting methodological information and limitations about adaptation to contracted faces. In experiment 2 of chapter 3 participants who adapted to the Christian contracted/Muslim expanded religious explicit condition show a consistent change in preference for contracted faces for both faces adapted to. However, for the Christian expanded/Muslim contracted religious explicit condition no opposing aftereffects occurred. In this condition, participants select similar amounts of contracted faces after adaptation for both face categories. Participants still preferred Christian contracted faces after adaptation, even though they adapted to expanded Christian faces. Furthermore, in experiment 3, all children show a preference for contracted Christian faces compared to expanded, whether they were adapted to Christian expanded or Christian contracted faces. In chapter 4, participants who adapted to diverse expanded faces still show some preference for contracted diverse faces after adaptation. Finally, in chapter 5 it was found that adaptation to contracted faces was slower to decay than expanded faces.

Combined these 3 experiments highlight that adaptation to contracted faces may not be equivalent to adaptation to expanded faces despite being physically equal (but opposite) distortions. These are not the first experiments to have found differences in adaptation strength to contracted faces compared to expanded. Previously Walsh et al. (2015) revealed a differing pattern of results for adaptation to contracted and expanded male and female faces. Participants in both adaptation groups who were adapted to contracted faces showed larger aftereffects compared to those who were adapted to expanded faces. Additionally, participants showed transfer aftereffects for contracted faces for both adaptation conditions (adapted to the contracted male or the contracted female groups). After adaptation preference for contracted directions for both sexes was observed, even though one was adapted to in the opposite direction. This is not the first time transfer aftereffects for contracted faces have been observed (Jaquet & Rhodes, 2008).

Even though we expect expanded and contracted faces to be psychological opposites of each other during adaptation, this is a computer-generated manipulation and may not be perceived as such. It is possible that the distortion that is created for contracted faces is perceived as more extremely distorted in some way than expanded faces. Though this is controlled for as much as possible in the lab, distorting and spherizing to similar degrees in both directions, differences in adaptation suggest that they are not perceived as equivocally distorted. The results of chapter 5 provided further insight into this methodological limitation and demonstrated that adaptation decay for contracted faces was also slower than expanded faces. As a norm-based view indicates stronger distortions result in larger adaptations (Rhodes et al., 2005; Robbins et al., 2007), it is quite possible contracted faces were viewed as more distorted and resulted in differences in adaptation compared to expanded faces.

**Future directions**

Chapter 2 revealed a long developmental trajectory to norm-based emotion perception skills. However, the results of experiment 2 have yet to be similarly explored in adults. In order to make a more direct comparison between adults and children and how they differ in reliance to norm-based emotion perception strategies, an adult sample could be the next step to explore. Additionally, as children as young as 4-years-old show some evidence of norm-based coding skills (Jeffery et al., 2010), extending this paradigm to 4- and 5-year-olds would be beneficial in further exploring children's developing face space.

The influence of social information on norm-based coding in chapter 3 reveals several aspects that can be further explored. The use of audio stimuli to heighten social relevance during adaptation was a novel methodology that should be examined across several other face categories. One example would be to examine other social categories that have already been explored via opposing aftereffects to determine if adding an audio cues enhances adaptation. Previously some sex opposing aftereffects experiments have only shown weak separable adaptation to male and female faces (Jaquet & Rhodes, 2008). Would adaptation to sex opposing aftereffects with explicit audio cue result in stronger aftereffects than without this social relevance? Additionally, to what extent do audio cues enhance adaptation? Though opposing aftereffects require physical distinctiveness during adaptation (Short & Mondloch, 2010), inducing this form of social relevance to faces that are not physically distinct has yet to be explored. This novel methodology should be further utilized to examine to what extent enhancing social relevance influences face space.

Additionally, as religious opposing aftereffects in 8-year-olds were not observed in chapter 3, there is much more to explore in regard to children's categorical face norms. There has been some difficulty adapting children to opposing aftereffects paradigms (Short et al., 2011, 2014), future research could consider including an audio cue to enhance adaptation. It is possible opposing aftereffects for religion were not observed in chapter 3 due to this category not being salient enough to the children during adaptation. It could be beneficial to use audio cues when adapting children to enhance social relevance, similar to how adaptation distortions have been increased to influence children's adaptation (Anzures et al., 2009; Short et al., 2011). Future studies could adapt 8-year-olds to sex and age opposing aftereffects, with and without audio cues to determine if this affects separable face norms.

The results from chapter 4 reveal new information about the ability to adapt to diverse face sets and group diversity as a cue to category membership during adaptation. However, this result was examined using White males as the homogenous face set, which leads to the question what would happen if the homogenous group was of a different race or a different gender. Future studies should manipulate the homogenous face set to determine if this affects adaptation. Additionally, this is the first evidence of adapting to a diverse group of faces which leads to the question if you could adapt to two groups of faces that are both diverse in some manner? How complex diverse group adaptation is should be further manipulated to explore the complexity of our face space.

Finally, chapter 5 was the first to reveal that opposing aftereffect adaptation results in a longer decay than other forms of adaptation to face aftereffects (Leopold et al., 2005; Rhodes et al., 2007). However, it is unknown whether this effect was due to the paradigm of adapting to two categories at once in opposing directions, the social significance from the audio cue, or a combination of both. Future studies should examine opposing aftereffects for other social categories such as sex and race, with and without audio cues. Additionally, a more direct examination of the decay of opposing aftereffects should be examined. Participants could return over multiple time points after adaptation, such as 24 hours, 2 days, and 7 days, to examine how slowly decay occurs. Finally, future research should directly compare adaptation to simple aftereffects and opposing aftereffects to determine if the decay difference is due to adapting to multiple templates at once.

**Conclusions**

The results from this dissertation provide new evidence on the reliance, development, representation, and manipulation of norm-based coding in adults and children. Together the results of these empirical chapters: 1) provide important information as to how adult-like face perception expertise develops throughout childhood, 2) contributes to the field of adaptation aftereffects, revealing the role of social significance on the representation of cognitive templates in face space and 3) revealed the persistence of adaptation to social category-specific face norms, highlighting the malleability of our face templates. The ability to perceive social-categorical information from faces is essential in a highly social species. Exploring how we make use of social information from faces can provide insight as to how we perceive differences in others.

## References

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face Adaptation and Attractiveness Aftereffects in 8-Year-Olds and Adults. *Child Development*, *80*(1), 178–191.

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., Welling, L. L. M., & Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition*, *107*(1), 353–365. https://doi.org/10.1016/j.cognition.2007.07.018

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. https://doi.org/10.1080/13506280802708024

Jaquet, E., & Rhodes, G. (2008). Face aftereffects indicate dissociable, but not distinct, coding of male and female faces. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(1), 101.

Jaquet, E., Rhodes, G., & Hayward, W. G. (2007). Opposite Aftereffects for Chinese and Caucasian Faces are Selective for Social Category Information and not Just Physical Face Differences. *Quarterly Journal of Experimental Psychology*, *60*(11), 1457–1467. https://doi.org/10.1080/17470210701467870

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition*, *16*(6), 734–753. https://doi.org/10.1080/13506280701350647

Jeffery, L., McKone, E., Haynes, R., Firth, E., Pellicano, E., & Rhodes, G. (2010). Four-to-six-year-old children use norm-based coding in face-space. *Journal of Vision*, *10*(5), 18–18.

Jeffery, L., Read, A., & Rhodes, G. (2013a). Four year-olds use norm-based coding for face identity. *Cognition*, *127*(2), 258–263.

Jeffery, L., Rhodes, G., McKone, E., Pellicano, E., Crookes, K., & Taylor, E. (2011). Distinguishing norm-based from exemplar-based coding of identity in children: Evidence from face identity aftereffects. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(6), 1824–1840. https://doi.org/10.1037/a0025643

Kloth, N., Pugh, C., & Rhodes, G. (2017). The contributions of temporal delay and face exposure to the decay of gaze direction aftereffects. *Journal of Vision*, *17*(3), 5–5. https://doi.org/10.1167/17.3.5

Kloth, N., & Rhodes, G. (2016). Gaze direction aftereffects are surprisingly long-lasting. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(9), 1311.

Kloth, N., & Schweinberger, S. R. (2008). The temporal decay of eye gaze adaptation effects. *Journal of Vision*, *8*(11), 4–4. https://doi.org/10.1167/8.11.4

Little, A. C, DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1578), 2283–2287. https://doi.org/10.1098/rspb.2005.3220

Little, Anthony C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition*, *106*(3), 1537–1547. https://doi.org/10.1016/j.cognition.2007.06.008

Nishimura, M., Maurer, D., & Gao, X. (2009). Exploring children's face-space: A multidimensional scaling analysis of the mental representation of facial identity. *Journal of Experimental Child Psychology*, *103*(3), 355–375. https://doi.org/10.1016/j.jecp.2009.02.005

Nishimura, M., Maurer, D., Jeffery, L., Pellicano, E., & Rhodes, G. (2008). Fitting the child's mind to the world: Adaptive norm-based coding of facial identity in 8-year-olds. *Developmental Science*, *11*(4), 620–627.

Rhodes, G., Robbins, R., Jaquet, E., McKone, E., Jeffery, L., & Clifford, C. W. (2005). Adaptation and face perception: How aftereffects implicate norm-based coding of faces. *Fitting the Mind to the World: Adaptation and after-Effects in High-Level Vision*, 213–240.

Robbins, R., McKone, E., & Edwards, M. (2007). Aftereffects for face attributes with different natural variability: Adapter position effects and neural models. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(3), 570–592. https://doi.org/10.1037/0096-1523.33.3.570

Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus Prototype Matching: Strategies of Perception of Emotional Facial Expressions in the Autism Spectrum. *Journal of Autism and Developmental Disorders*, *37*(2), 187–196. https://doi.org/10.1007/s10803-006-0151-9

Schweinberger, S. R., Zäske, R., Walther, C., Golle, J., Kovács, G., & Wiese, H. (2010). Young without plastic surgery: Perceptual adaptation to the age of female and male faces. *Vision Research*, *50*(23), 2570–2576. https://doi.org/10.1016/j.visres.2010.08.017

Short, L. A., Hatry, A. J., & Mondloch, C. J. (2011). The development of norm-based coding and race-specific face prototypes: An examination of 5-and 8-year-olds' face space. *Journal of Experimental Child Psychology*, *108*(2), 338–357.

Short, L. A., Lee, K., Fu, G., & Mondloch, C. J. (2014). Category-specific face prototypes are emerging, but not yet mature, in 5-year-old children. *Journal of Experimental Child Psychology*, *126*, 161–177. https://doi.org/10.1016/j.jecp.2014.04.004

Short, L. A., & Mondloch, C. J. (2010). The Importance of Social Factors is a Matter of Perception. *Perception*, *39*(11), 1562–1564. https://doi.org/10.1068/p6758

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B., & Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. https://doi.org/10.1016/j.psychres.2008.05.006

Valentine, T. (1991). A Unified Account of the Effects of Distinctiveness, Inversion, and Race in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *43*(2), 161–204. https://doi.org/10.1080/14640749108400966

Walsh, J. A., Vida, M. D., Morrisey, M. N., & Rutherford, M. D. (2015). Adults with autism spectrum disorder show evidence of figural aftereffects with male and female faces. *Vision Research*, *115*, 104–112. https://doi.org/10.1016/j.visres.2015.08.010

Walsh, J. A., Vida, M. D., & Rutherford, M. D. (2014). Strategies for Perceiving Facial Expressions in Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *44*(5), 1018–1026. https://doi.org/10.1007/s10803-013-1953-1

Watson, T. L., & Clifford, C. W. G. (2006). Orientation dependence of the orientation-contingent face aftereffect. *Vision Research*, *46*(20), 3422–3429. https://doi.org/10.1016/j.visres.2006.03.026