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Why Are Attractive Faces Preferred? An Electrophysiological Test of Averageness Theory

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Why Are Attractive Faces Preferred? An Electrophysiological Test of Averageness Theory

by

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Dissertation

Presented to the Faculty of the Graduate School of
The University of Texas at Austin
in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

The University of Texas at Austin
May, 2007

Dedication

This dissertation is dedicated to my husband, Wes Hodgin. Without his tireless support, patience, and inspiration, this work would not have been possible.

Acknowledgements

First, I would like to thank my advisor, Judith Langlois, for her endless support, encouragement, and guidance. I am grateful and honored to have had the opportunity to work with her, learn from her, and know her. She has been a tremendous source of inspiration and is without a doubt the best mentor and advisor I will ever have.

I also want to express my thanks and appreciation to my family, my husband, Wes Hodgin, my parents Jim and Gaye Griffin, my sister, Katie Griffin, my grandparents, Kathleen Griffin and Robert and Mavis Isenhour. My family has always provided me with the passion, support, guidance, and enthusiasm that I need to meet challenges and reach my goals. I owe all that I have accomplished to their deep confidence, love, and encouragement.

My fellow graduate students and colleagues also deserve special thanks. Specifically, I would like to thank Teresa Taylor-Partridge, Amber Hardaway, Connor Principe, Lisa Rosen, Jennifer Rennels, Rebecca Hoss, and Matthew Bronstad. It has been a great pleasure to work with such helpful, talented, and fun colleagues.

I would also like to thank the members of my dissertation committee: Rebecca Bigler, William Swann, Catharine Echols, and Natasha Beretvas. My committee members spent many hours reading and discussing my work and I appreciate all of the effort that they devoted to guiding and challenging me throughout the conduct of this research. I would also like to express my deep appreciation to Jacqueline Woolley for all the support and advice that she provided throughout my graduate career.

Finally, I would like to express my appreciation to the many parents, children, and students who agreed to participate in my studies as well as the many wonderful undergraduate research assistants who assisting in running my studies. Without them and their support, this research would not have been possible.

Why Are Attractive Faces Preferred? An Electrophysiological Test of Averageness Theory

Publication No._____________

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The University of Texas at Austin, 2007

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Numerous studies provide evidence that 6-month-old infants have visual preferences for faces judged by adults to be attractive well before these preferences might be acquired through socialization mechanisms (e.g. Langlois et al., 1987; Slater et al., 1998). *Why* do infants and adults prefer attractive faces?

Averageness theory asserts that attractive faces are more 'average' in configuration and closely resemble the mean of a population of faces and are thus more familiar, typical, and 'face-like', than faces that deviate (e.g., unattractive faces) from the average configuration (Langlois & Roggman, 1990). When faces are averaged together, the resulting average configuration is judged to be highly attractive (e.g., Langlois & Roggman, 1990). Fluency theories suggest that fluent processing of prototypical exemplars (e.g., attractive faces, averaged faces) evokes positive affect (e.g., Winkielman et al., 2003). Therefore, because adults and even 6-month-olds can form prototypes of the faces they experience (e.g., Rubenstein et al., 1999), they may prefer attractive faces because they are more prototypical, and thus, more quickly and easily processed than less attractive faces.

I tested fifty 6-month-old infants and forty-four adults and used event-related potentials (ERP) to record their brain activity in response to averaged, attractive, and unattractive faces. Consistent with averageness and fluency theories, results revealed lower amplitudes and shorter latencies to less attractive faces in infant and adult ERP components associated with face processing. Infant ERPs also showed a pattern of activity that suggested that attractive faces are processed as familiar compared to less attractive faces. The results suggest that more attractive faces are more fluently processed than less attractive faces and thus, both infants and adults may prefer attractive faces because they are more quickly and easily processed.

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Chapter One:

Introduction and Literature Review

Thousands of studies and decades of research have shown that adults and children show notable similarity in their judgments of facial attractiveness and prefer attractive over unattractive people. Children and adults attribute positive traits and behaviors (e.g., nice) to attractive people and negative traits and behaviors (e.g., mean) to unattractive people. Furthermore, both children and adults treat attractive people more favorably than unattractive people. Children also prefer and select attractive peers as friends and interaction partners. Even parents (Langlois, Ritter, Casey, & Sawin, 1995) and teachers (e.g., Clifford & Walster, 1973; Felson, 1980) show differential treatment of and expectations for children on the basis of facial attractiveness (for a review of the attractiveness literature see Langlois et al., 2000).

While it is often assumed that attractiveness stereotypes are gradually acquired through exposure to beauty ideals and attitudes portrayed by the media and other socialization agents (e.g., parents, peers), children as young as 3 years evidence stereotyped beliefs consistent with the “beauty-is-good” stereotype. Moreover, even infants show visual preferences for attractive over unattractive Caucasian female faces and these preferences for attractive faces extend to African-American female faces, Caucasian male faces, and other infants’ faces (Langlois, Ritter, Roggman, & Vaughn, 1991). Infants as young as 2-3-months show visual preferences for faces judged by adults to be attractive well before these preferences might be acquired through gradual socialization (e.g., Langlois, Roggman, Casey, & Ritter, 1987; Langlois, Ritter, Roggman, & Vaughn, 1991; Samuels & Ewy, 1985; Slater, Von der, Schulenburg, Brown, Badenoch, & Butterworth, 1998). By 12 months, infants show *social* preferences for an attractive over an unattractive individual (i.e., greater approach and positive affect towards an attractive stranger, greater avoidance and negative affect towards an unattractive stranger; Langlois, Roggman, & Reiser-Danner, 1990).

Given that infants show both visual and social preferences for attractive faces consistent with those of older children and given the extensive evidence for the existence, exercise, and negative consequences associated with attractiveness stereotypes, it is both logical and important to consider the question: *Why* are attractive faces preferred? The answer to this question is both intriguing and important to understanding mechanisms underlying the development of attractiveness stereotypes.

AVERAGENESS THEORY

Fortunately a testable theory has been proposed to explain *why* both infants and adults prefer attractive people and faces: Averageness theory is a cognitive theory that is both a testable and parsimonious explanation for attractiveness preferences (see Langlois & Roggman, 1990; Langlois et al., 1994). This theory rests upon the assertion that attractive faces are more "average" in configuration (i.e., closer to the mean of the population) and are thus more familiar, typical, and "face-like" than faces that deviate (e.g., unattractive faces) from the average configuration of a population of faces.

To test the premise that faces that represent the mean value of a population of faces are perceived as attractive, Langlois & Roggman (1990) digitized groups of individual male and female faces and then averaged them together mathematically to create composite, or “averaged” male and female faces that represented the mean value of the samples. Adults rated the individual male and female faces as well as the “averaged” male and female face images for facial attractiveness. Consistent with averageness theory, adults’ gave significantly higher mean attractiveness scores to male and female “averaged” faces than to individual male and female faces. Moreover, the mean attractiveness ratings attributed to the male and female “averaged” faces were higher than almost all of the individual male and female faces that were mathematically averaged to create the “averaged” faces.

A variety of studies that followed Langlois & Roggman (1990) support the theory that faces that are more “average” or prototypical, are perceived as attractive. For example, when at least 16 individual faces are averaged together mathematically, adults perceive the resulting facial “average” or prototype, as attractive, familiar, and typical (e.g., Langlois, Roggman, & Musselman, 1994). Furthermore, more recent studies that have tested the effect of exposure to facial distortions on adults’ perceptions of facial averageness and attractiveness have shown that while adults’ perceptions of averageness shifted with exposure to different types of faces, faces rated high in averageness were also rated high in attractiveness (e.g., Rhodes, Jeffrey & Watson, 2003). Rhodes, Jeffrey, & Watson (2003) exposed participants to a series of faces that had been distorted. Participants rated the facial images for attractiveness and averageness before and after adaptation to a range of faces that were distorted either by expansion or compression from the center or laterally. Adaptation to a range of distorted faces produced changes in which face participants rated as “most normal” or typical in appearance. Regardless of the type of facial distortion that participants were adapted to, however, they rated the faces that they perceived as more typical or “average” in appearance as most attractive. These findings support averageness theory and indicate that averaged or prototypical faces are perceived as attractive.

RELATIONS BETWEEN AVERAGENESS, PREFERENCES, AND AFFECT

One reason that attractive and prototypical faces may be preferred is that prototypical stimuli are easily processed (Rosch, 1978) and ease of processing is associated with positive evaluations and positive affect (e.g., Winkielman & Cacioppo, 2001; Winkielman, Schwarz & Nowak, 2002). Preferences for prototypicality are not limited to the category of faces. Prototypes of categories of objects (Whitfield & Slatter, 1979) and music (Smith & Melara, 1990) have been shown to be preferred and viewed as good or representative examples of their category. Further, adults perceive prototypical birds and fish (Halberstadt & Rhodes, 2003) and dot and geometric patterns, as attractive (Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). Even young infants are adept at forming prototypes, or representations of the mean of a category (e.g., Bomba & Siqueland, 1983; Rubenstein, Kalakhanis, & Langlois, 1999; Strauss, 1979; Younger, 1985), and prefer prototypical faces (e.g., Rubenstein, Kalakhanis, & Langlois, 1999). Numerous studies show that infants have the capacity to form cognitive prototypes, including prototypes of faces: Infants exposed to a series of individual faces respond to the mean value (prototype) of these faces as if it is *familiar* even though they have *never seen it before*, suggesting that infants are capable of forming a cognitive prototype of the faces they experience (de Haan, Johnson, Mauer, & Perrett, 1999; Rubenstein, Kalakhanis, & Langlois, 1999; Walton & Bower, 1993).

Consistent with averageness theory, these findings from previous studies of infants and adults suggest that averaged faces are perceived as both attractive and prototypical, but if attractive faces are preferred because they are similar in configuration to the population mean, or average, are there data to show that attractive faces are, in fact, more similar to "averaged" faces than less attractive faces? Indeed, recent findings support the assertion that attractive faces are similar in configuration to averaged faces. Bronstad and Langlois (2006) tested a computational model of facial averageness based on adults' similarity ratings of groups of faces and used multidimensional scaling (MDS) and principal components analysis (PCA) to quantify similarity of individual faces to an averaged face. They found that attractiveness ratings predicted measured similarity to an averaged face. More attractive faces are, in fact, more similar to averaged faces than less attractive faces.

Thus, given: 1) infants form cognitive representations of the mean or prototype of faces they experience (e.g., Rubenstein, Kalakanis & Langlois, 1999); 2) infants and adults perceive averaged faces as familiar and adults perceive averaged faces as attractive and prototypical (e.g., de Haan et al., 1999; Langlois, Roggman, & Musselman, 1994; Rubenstein, Kalakanis & Langlois, 1999); *and* 3) attractive faces are similar in configuration to averaged faces (Bronstad & Langlois, 2006), then attractive faces may be preferred because they are more familiar, prototypical, and "face-like" than less attractive faces. While evidence exists to support these three tenets of averageness theory, no direct evidence exists to support the prediction that attractive faces are preferred because they are more prototypical than less attractive faces, or, more importantly, to identify the specific processes that underlie preferences for attractive faces. Nevertheless, while no direct evidence exists to support the prediction that attractive faces are more prototypical and “face-like” than less attractive faces, recent findings do provide some indirect evidence in support of this claim.

Rosen, Griffin, Hoss, Bronstad & Langlois (2005) tested 4-5-year-old children and adults in a reaction time task to determine whether averaged and attractive faces are categorized as faces more quickly and accurately than unattractive faces. They predicted that if averaged and attractive faces are more prototypical and “face-like” than unattractive faces, children and adults should be faster and more accurate at categorizing them as face versus non-face stimuli than unattractive faces. As expected, results showed that participants categorized averaged and attractive female faces as faces significantly faster than unattractive faces. Likewise, Hoss, Ramsey, Griffin & Langlois (2005) found that attractiveness aided children’s classification of female faces and adults’ classification of male and female faces on the basis of gender in a similar reaction time study. Taken together, these data that indicate that attractive faces are often more quickly and accurately identified as faces and classified by gender suggest that attractive faces are in fact, more prototypical, or “face-like” than unattractive faces.

A recent study by Winkielman, Halberstadt, Fazendeiro, and Catty (2006) showed that the prototypicality of dot patterns predicted attractiveness ratings and categorization speed, but also tested the link between processing fluency and positive affect by measuring facial electromyography (EMG). Results showed that prototypical stimuli were more quickly categorized and elicited greater activation of the facial muscles used to form a smile as compared to less prototypical stimuli. These findings indicate that prototypical stimuli (e.g., attractive faces) are fluently processed and that fluent processing evokes positive affect. The results are consistent with fluency theories that maintain that fluent processing results in positive evaluations of prototypical stimuli (e.g., attractive faces) due to the misattribution of the positive affect elicited by fluent processing to the stimuli (Reber, Winkielman, Schwarz, 1998; Winkielman & Cacioppo, 2001; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006; Winkielman, Schwarz, Fazendeiro, & Reber, 2003; Winkielman, Schwarz, & Nowak, 2002).

USING EVENT-RELATED POTENTIALS TO TEST AVERAGENESS THEORY

Reaction time data from previous studies (e.g., Hoss, Ramsey, Griffin & Langlois, 2005; Rosen, Griffin, Hoss, Bronstad & Langlois, 2005) provide indirect evidence in support of the assertion that attractive faces are preferred because they are more prototypical and better representatives of faces than less attractive faces, yet this prediction provided by averageness theory requires additional support. More importantly, the assumption that follows from this assertion regarding the process that underlies attractiveness preferences (attractive faces are processed more fluently than less attractive faces) requires investigation. To make a strong claim that attractive faces are prototypical and more quickly and easily processed than less attractive faces, more direct measures of the time course of face encoding and magnitude of processing of attractive and unattractive faces are necessary. If attractive faces are prototypical and thus processed more fluently than less attractive faces and fluent processing is associated with positive affect, then attractive faces may be preferred simply because they are more fluently processed than less attractive faces.

Because reaction time tasks and other behavioral measures can only provide an index of differential processing of attractive versus unattractive faces at the level of behavioral response and because we still do not have a complete answer to the question: *Why* are attractive faces preferred?, electrophysiological studies designed to measure the encoding and face processing in real time with high temporal resolution (ms) are critical. Electrophysiological measures are particularly useful for testing the predictions of averageness theory because they can be used to determine why attractive faces are preferred and elucidate the mechanisms that underlie attractiveness preferences. Electrophysiological indices of face processing not only allow for a more direct examination of differential magnitude and speed of processing, but also allow for a more direct comparison between adult data and data collected from nonverbal infants who cannot complete reaction time and other active experimental tasks.

If attractive faces are preferred because they are more similar to averaged faces than less attractiveness faces, and thus more familiar, prototypical, and better examples of faces, then attractive faces should be more quickly and easily processed by adults and infants than less attractive, less prototypical (i.e., unattractive) faces. Although a number of methods could be employed to test this hypothesis, event-related potentials (ERPs) in particular provide a more direct and informative means by which to measure the time course and neural processing of faces varying in attractiveness and prototypicality.

ERPs are changes in electroencephalogram (EEG), or neural activity, generated by the simultaneous firing of populations of neurons in the brain in response to discrete events (e.g., Rugg & Coles, 1995; De Boer, Scott, & Nelson, 2004). During the presentation of multiple stimulus events, ERP waveforms are derived from the EEG by time locking scalp-recorded EEGs to these events and averaging the neural activity across the events. It is through the process of averaging ongoing EEG signals elicited by a stimulus or stimulus class that the signal to noise ratio of EEG data is increased to the point that smooth waveforms labeled as specific ERP waveform components can be extracted. These ERP components (see Figures 3-5 for examples of infant and adult ERP components) are thought to reflect specific perceptual and cognitive processes (e.g., detection of familiarity) and information processing in the brain (Nelson, 1993, 1994; Richards, 2000) and are collected through non-invasive scalp recordings. For a review of infant, child, and adult ERP components see: Csibra, Kushnerenko, & Grossmann, in press; Nelson, 1994, 1995, 1996; Nelson & Luciana, 1998; Nelson & Monk, 2001; and Taylor & Baldeweg, 2002. (See Table 2 for a summary of ERP terminology)

N290 and P400 are face-sensitive components that are recorded in infants and thought to reflect the structural encoding and perceptual processing of faces (e.g., de Haan & Nelson , 1999; de Haan, Johnson, & Halit, 2003; de Haan, Pascalis, & Johnson, 2002; Csibra, Kushnerenko, & Grossmann, in press). In adults, there is one component that is sensitive to faces and face-like stimuli (N170), that is typically recorded (e.g., Bentin, Allison, & Puce, 1996; Eimer, Holmes, & McGlone, 2003) and it is approximately twice as large to face versus non-face stimuli (e.g., hands, animals) (e.g., Bentin, Allison, & Puce, Perez, & McCarthy, 1996). The infant Nc component, on the other hand, has been associated with activation of processing resources to highly familiar, salient, or attention-grabbing stimuli (e.g., Courchesne, Ganz, & Norcia, 1981; Karrer &

Monti, 1995; Nelson & Monk, 2001; Snyder, Webb, & Nelson, 2002) while a late-latency slow-wave, PSW, has been linked to processing of a partially encoded or relatively novel stimulus (de Haan & Nelson, 1997, 1999; Nelson, 1994; Snyder, Webb, & Nelson, 2002).

Different ERP components not only reflect certain perceptual and cognitive processes, but have different characteristic latencies and amplitudes that reflect the speed (latency) and magnitude (amplitude) of processing for a stimulus or stimulus class. For example, the amplitude of the N290 (average latency = 290ms) and P400 (average latency = 400ms) components in infants and the N170 (average latency = 170ms) component in adults, are sensitive to facial stimuli and the degree to which visual stimuli are "face-like" or typical examples of faces (e.g., Csibra, Kushnerenko, & Grossmann, in press; de Haan et al., 2002; Rossion et al., 2000).

Because traditional adult (e.g., reaction time) and particularly infant research paradigms and measures (i.e., preferential looking, habituation, looking time) only provide indirect evidence of information processing, ERP assessments are important because they allow us to investigate the onset of stimulus perception and subsequent information processing in a more direct way (Csibra, Tucker, & Johnson, 1998; de Haan & Nelson, 1997; de Haan & Nelson, 1999; Nelson, 1994; Richards, 2000). ERPs also provide a real time reflection of encoding and processing with high temporal resolution. Furthermore, by recording ERPs, it is possible to obtain measures of brain activation either before an overt behavioral response to a stimulus occurs or in the absence of an overt behavioral response (Nelson & Collins, 1991; Richards, 2000).

Thus, research involving nonverbal infants with a limited range of behavioral responses benefits a great deal from the incorporation of ERP studies. ERP methodology can be used to determine whether infants: (a) process and encode averaged and attractive faces more fluently than less attractive faces and (b) respond to averaged and attractive faces as if they are familiar, by measuring the time course and neural correlates of processing of averaged, attractive, and unattractive faces. Given its high temporal resolution, ERP methodology provides an excellent and appropriate tool for examining differential speed (ERP latency) and magnitude of processing (ERP amplitude) and encoding of faces varying in attractiveness and prototypicality in both adults and infants.

OVERVIEW OF STUDIES

This research was designed to answer three questions: 1) Are averaged and attractive faces processed more fluently than unattractive faces?; 2) Are averaged and attractive faces perceived as familiar as compared to unattractive faces?; and 3) What is the degree of concordance between infant and adult processing of facial attractiveness and prototypicality.

I designed two ERP studies to determine if infants and adults process never-before-seen averaged faces (created from 16 and 32 individual faces) and individual attractive faces more fluently than unattractive faces and as if they are familiar as predicted by averageness theory (Langlois, Roggman, & Musselman, 1994). Recent research has shown that ease of perceptual processing (e.g., quick recognition, accurate classification) is associated with positive evaluations and affect (e.g., Winkielman & Cacioppo, 2001; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006; Winkielman, Schwarz & Nowak, 2002). Thus, if attractive faces are preferred because it is easier for infants and adults to process and encode attractive faces (because they are more prototypic and "face-like"), then they should also show significantly shorter *latencies* for averaged and high attractive relative to unattractive faces for face-sensitive ERP components.

Studies from the neuroimaging literature indicate that repetition priming reduces blood flow to several areas of the brain and this reduction in flow is associated with reduced neural activation, (e.g., Schacter & Wagner, 1999; Schacter, Gabrieli, Desmond, & Glover, 1998). ERP studies indicate that neurons in non-human primates show a reduction in firing in response to stimulus repetition (see Desimone & Duncan for a review). Further, Henson, Shallice, and Dolan (2000) found that neural activation decreased when participants saw *familiar* faces and symbols, but that neural activation increased when participants saw *novel* faces and symbols. Together, these findings suggest that stimuli that are perceived as familiar (e.g., averaged, attractive faces) should elicit lower amounts of brain activation (e.g., ERP amplitudes) than stimuli that are perceived as unfamiliar or novel (e.g., unattractive faces).

Therefore, because prototypical and familiar stimuli are easily processed (e.g., recognized, classified) and require fewer processing resources (e.g., Winkielman, Schwarz, Fazendeiro, & Reber, 2003), infants should show lower *amplitudes* in face-sensitive ERP components to averaged and attractive faces that are perceived as prototypical, “face-like”, and familiar compared with unattractive faces. Such a finding for ERP amplitude would be consistent with the results of the one existing study of ERP component modulation by facial attractiveness that showed that the face-sensitive adult ERP component (N170) showed lower amplitudes to attractive versus unattractive faces (Halit, de Haan, & Johnson, 2000).

Finally, previous research has demonstrated that infants are capable of forming prototypes of female faces and that they prefer averaged female faces (Rubenstein, Kalakanis & Langlois, 1999). Thus, averaged female faces, though *never-before-seen*, should evoke ERP responses similar to those shown to familiar faces because they are prototypical. Novel, high attractive faces should evoke responses similar to those for averaged faces because attractive faces are similar to averaged faces in configuration. In contrast, unattractive faces should evoke ERPs that characterize responses to unfamiliar faces because unattractive faces are less average in configuration (See Tables 1 and 3 for summaries of ERP components and predictions).

Chapter Two:

Experiment 1

I designed Experiment 1 with two primary goals. First, I designed the experiment to determine whether averaged and attractive faces are processed more fluently by infants than unattractive faces, as predicted by averageness theory. If so, infants' face-sensitive ERP components (N290, P400) should show lower amplitudes and shorter latencies for averaged and attractive versus unattractive faces. Such lower amplitudes and shorter latencies would suggest that attractive faces are more fluently processed than less attractive faces because they indicate lower amounts of neural activation and faster processing speed. Second, I designed this study to test whether averaged and attractive are processed as more familiar than unattractive faces due to their prototypicality and consistent with previous behavioral data (e.g., Langlois, Roggman, & Musselman, 1994; Rubenstein, Kalakanis & Langlois, 1999). If more attractive faces are perceived as familiar compared to less attractive faces, then averaged and attractive faces should evoke responses associated with processing of familiar stimuli in infants' familiarity-sensitive ERP components (Nc, PSW), whereas unattractive faces should evoke ERP responses that are associated with processing of a partially encoded, less familiar stimulus.

METHOD

Participants

Participants were fifty 6-month-old infants (21 female, 29 male, mean age = 183 days) born within three weeks of their due date and tested within 5 days of their 6-month birthday. An additional 63 infants were tested, but their data were excluded for the following reasons: poor impedances or excessive mechanical artifact in the EEG signal (8), infant was fussy/fell asleep or produced excessive movement artifact during the task (24), infant was born prematurely or was too old to participate in the study (10), equipment error (12), sensory impairment, neurological disorder, or iron deficiency (3), and less than 10 artifact-free trials at one or more electrodes for each face type (6). This attrition rate is similar (e.g., de Haan & Nelson, 1997, 1999; Quinn, Westerlund & Nelson, 2006) to that reported in previous ERP studies of 6-month-olds. Power analyses indicated that the final sample size was large enough to detect group differences if present (power $\geq .80$). The infants were predominantly Caucasian (68% Caucasian, 2.0% Asian Pacific Islander, 12% Hispanic, 3% African-American, 14% two or more races, and 1% unknown).

I tested 6-month-old infants for three reasons: 1) they show robust attractiveness preferences (e.g., Langlois, Roggman, Casey, Ritter, & Rieser-Danner, 1987); 2) can categorize faces based on attractiveness (Ramsey, Langlois, Hoss, Rubenstein, & Griffin, 2004); and 3) form prototypes of the faces they experience (e.g., Rubenstein, Kalakhanis, & Langlois, 1999).

Stimuli

Stimuli were 24 color images of adult female faces. Sixteen of the images were of individual, college-aged female faces (eight attractive, eight unattractive) selected from an existing photo database of over 5000 images of undergraduate women. Eight of the images were mathematically averaged female faces (i.e., Langlois & Roggman, 1990). I constructed the averaged faces in three steps. First, I randomly selected faces from an independent sample of adult female faces that did not include the 16 individual stimulus faces, and with no face represented in more than one facial average. Second, to create the averaged face images, I scanned and digitized the individual images, mathematically averaged the matrices of pixel values representing the images to be averaged, and created the averaged facial image from the resulting averaged matrix values (see Langlois, et al., 1994 for additional details on the averaging process). Third, following creation of the averaged images, I equated them for image brightness, color balance, luminance, and contrast using Adobe Photoshop^{TM}. All of the facial images depicted individuals posed with neutral expression, directly facing a camera, wearing a white sheet to mask clothing, and were placed on a standard white background. I created 8 facial averages representing 5 levels of averaging. I created two 2-face averages (e.g., two individual faces averaged together), two 4-face averages (e.g., four individual faces averaged together), two 8-face averages (e.g., eight individual faces averaged together), one 16-face mathematical average, and one 32-face average.

I included only one 16-face average and one 32-face average for two reasons. First, unlike facial averages created from 2-8 individual faces, facial averages created from 16 or more faces look very similar in appearance even when they are constructed from different sets of faces (see Langlois & Roggman, 1990). Therefore, if participants saw more than one example of a 16- or 32-face average, they would not distinguish between the exemplars. Thus, the experimental task would be altered and the 16- and 32-face averages would be perceived to be presented with *greater* probability than all other stimulus faces. Second, in order to test the prediction that averaged, or prototypical faces that represent the mean configuration of a population of faces (i.e., faces constructed from 16 or more individual faces) are perceived as familiar due to their prototypicality, it is necessary to test for a familiarity response to these faces that is distinct from a familiarity response that derives from familiarity related to stimulus repetition or probability of presentation. Adult and infant ERPs to familiar stimuli are modulated not only by *a priori* familiarity (e.g., a facial configuration similar to the average configuration of the population), but also by stimulus repetition and perceived probability of presentation (e.g., 20% vs. 80% probability) (e.g., Rugg & Coles, 1995; de Haan & Nelson, 1999; Richards, 2003). Therefore, to ensure that any familiarity response recorded to averaged faces in this study could be attributed solely to *a priori* familiarity associated with facial prototypicality, I showed stimuli in this study with equal probability and presented just one 16- and one 32-face exemplar to participants.

Groups of at least 40 adults, approximately half male, half female, previously rated the 16 individual faces (8 attractive, 8 unattractive) for attractiveness on a 7-point Likert scale (1 = very unattractive, 7 = very attractive). To ensure that the faces were still perceived as low and high in attractiveness following image processing and to obtain attractiveness ratings for the 8 averaged faces, an independent sample of 58 undergraduate students (34 female, 24 male) of varying racial backgrounds rated the stimuli for facial attractiveness on a 7-point Likert scale with high interrater reliability, alpha = .98. The mean attractiveness ratings for the unattractive faces ranged from 1.81 to 2.93 (*M* = 2.06), the mean ratings for the attractive faces ranged from 4.10 to 5.93 (*M* = 4.79), and the ratings for the mathematically averaged faces ranged from 3.36 to 5.82 (*M* = 4.94). The mean attractiveness ratings for the 16-face and 32-face averages were 5.13 and 5.82. If attractive faces are preferred because they are more prototypical, then the facial attractiveness ratings for the stimuli should be highly correlated with facial typicality ratings. Thus, a second group of 63 undergraduate students (26 female, 37 male) rated the faces for typicality on a 7-point Likert scale (1 = not at all typical, 7 = very typical), with high interrater agreement (alpha = .93). The mean typicality ratings for the unattractive faces ranged from 3.04 to 4.06 (*M* = 3.12), the mean ratings for the attractive faces ranged from 4.00 to 4.80 (*M* = 4.34), and the ratings for the mathematically averaged faces ranged from 3.73 to 5.23 (*M* = 4.51). The mean typicality ratings for the 16-face and 32-face average were 5.13 and 5.23. The correlation between the mean attractiveness and typicality ratings for the 24 stimulus faces was high, *r* = .90

Procedure

Similar to de Haan and Nelson (1997), 6-month-olds saw the 24 images of adult female faces, shown one at a time in random order, in blocks with equal probability, on a computer monitor. Each test trial consisted of: 1) a 100ms measure of baseline brain activity in the absence of stimuli; and 2) the presentation of one of the stimulus faces for 500ms. I collected scalp recordings of EEG from 40 total frontal, temporal, midline, parietal and occipital electrodes using a Neuroscan Quik-Cap electrode cap configured according to the 10-20 system (Jasper, 1958, see Figure 1) until 1200ms following stimulus presentation. All signals were sampled at a rate of 1000 Hz and recorded with a Neuroscan Scan 4.3 system and NuAmps amplifier.

Infants sat on their parent's lap 60 cm in front of a computer monitor and viewed the stimulus faces. The facial images subtended approximately 10 degrees visual angle. During the study, a video camera positioned below the computer monitor recorded the infant's face and eyes and an experimenter observed the infant on a television monitor and recorded their attention on each trial by pressing keys on a computer keyboard. To assess reliability of attention coding for each participant, two independent observers, blind to the stimuli, coded visual attention from video tapes made of each participant during the study. Reliability was high (alpha = .98).

DATA ANALYSIS

Only those data recorded with electrical impedances of less than 10kΩ (e.g., Carver, Bauer, & Nelson, 2000) from participants who provided data for a minimum of 10 trials for each face type (attractive, unattractive, averaged) for each electrode, and for trials in which the participant attended to the stimulus were included the data analyses. Infants completed an average of 105 trials. In all of the primary analyses, I compared mean ERP responses to the individual attractive, individual unattractive, and 16- and 32-face averaged faces.

I compared mean responses to attractive and unattractive faces versus the 16- and 32-face averages only for two reasons. First, because participants see multiple presentations of each stimulus so that an ERP waveform can be extracted from background neural activity, or noise (e.g., Rugg & Coles, 1995; Richards, 2003; De Boer, Scott, & Nelson, 2004), ERP waveforms can be derived from multiple presentations of either a single stimulus (e.g., 32-face average) or stimulus category (e.g., unattractive faces). Second, in order to test the predictions of averageness theory, ERPs to faces that represent the average facial configuration of the population of faces must be compared with non-averaged faces. Thus, I compared ERPs to attractive and unattractive faces to ERPs to 16- and 32-face averages because facial averages created from a small sample of individual faces (e.g., 2-, 4-face average) represent sample sizes too small to approach the mean facial configuration of the population of faces.

I excluded ERP signals that exceeded plus or minus 150mV from all analyses because recordings exceeding this voltage range are non-biological signals that can be attributed to excessive movement, eye blinks, or mechanical artifact and noise (e.g., DeBoer, Scott, & Nelson, 2004). The data were digitized on-line and edited for artifacts (e.g., eye movements) off-line. Consistent with previous ERP studies of face perception (e.g., Carver, de Haan, Pascalis, & Johnson, 2002); I filtered the data using a bandpass filter of 0.1-45Hz to extract electrophysiological signals related to brain activity and attenuate signals at lower and higher frequencies associated with physiological and electrical noise (60 Hz noise from electrical devices). Next the data were baseline corrected (average voltage during the 100ms pre-stimulus baseline was subtracted from the voltages recorded following baseline) and averaged to create ERP waveforms for each face type for each participant. In order to compare group level data and compare mean ERP amplitudes and latencies to attractive, unattractive, and averaged faces, the individual ERP waveforms for each participant must be averaged together. Therefore, I averaged waveforms for individual participants to create grand averaged waveforms. Analysis of the data for outliers and normality indicated that there were no outliers and the distribution was not skewed.

Following the creation of grand averaged waveforms, I conducted repeated-measures analysis of variance (RMANOVA) to determine the effect of attractiveness and prototypicality on ERP waveform latency and peak amplitude. For late-latency slow wave (PSW), I analyzed average amplitudes because slow waves show no discernable peak. I conducted analyses for the following ERP components of interest: N290, P400, Nc, and PSW. See Figure 4 for examples of N290 and P400, and Figure 5 for examples of Nc and PSW.

I used the following standard time windows to identify the ERP waveforms of interest for all analyses: N290 (120-336ms), P400 (296-460ms), Nc (400-800ms), and PSW (800-1700ms). I identified the peak amplitude of each component by determining the highest voltage in the relevant time window. I identified peak latency by determining the time point at which each peak occurred following stimulus presentation. I conducted separate ANOVAs for the ERP components of interest for the two primary dependent variables (latency, amplitude) for the N290, P400, and Nc components, and ANOVAs for average amplitude only for the PSW component.

Face-Sensitive ERP Components

N290 COMPONENT ANALYSES. I conducted separate RMANOVAs to determine the effect of attractiveness on magnitude (N290 amplitude) and speed of processing

(N290 latency) for temporal and occipital electrodes. Face type (averaged, attractive, unattractive) and electrode (T3, T4, T5, T6) were the within-participants variables and participant sex was the between-participants variable for the temporal analysis. Face type (averaged, attractive, unattractive) and electrode (O1, O2, Oz) were the within-participants variables and participant sex was the between-participants variable for the occipital analysis. I included electrodes T3-T6 from temporal regions and O1, O2, and Oz from occipital regions only in the analyses because the N290 component is typically recorded at these specific sites (e.g., de Haan & Nelson, 1997, 1999; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007) and because these particular electrode groups showed prominent N290 deflections in the specified time window (See Figure 2 for an illustration of specific electrode locations).

Because N290 is a face-sensitive component, if averaged and attractive faces are more prototypical than unattractive faces, they should require less effortful processing to be recognized and processed as a face by the brain. Thus, I predicted that averaged and attractive faces would elicit significantly shorter latencies and lower amplitudes than unattractive faces. I also calculated the correlation between infants' mean amplitude and latency for the N290 component. If perceptual fluency in face processing is reflected by both shorter latencies and lower amplitudes, then N290 amplitude and latency should be positively correlated.

P400 COMPONENT ANALYSES. I conducted an analysis that was identical to the N290 analysis for the P400 component except that I only compared mean amplitudes and latencies at the Oz occipital electrode for the occipital analysis because Oz was the only occipital electrode to show a prominent P400 peak. Like N290, because P400 is face-sensitive, if averaged and attractive faces are more prototypical than unattractive faces, then they should elicit significantly shorter latencies and lower amplitudes than unattractive faces. As in the N290 analysis, I determined the correlation between infants' mean amplitude and latency for the P400 component. If fluent face processing is signaled by both shorter latencies and smaller amplitudes, then P400 amplitude and latency should be positively correlated.

Familiarity-Sensitive ERP Components

NC COMPONENT ANALYSES. To determine the effect of attractiveness on Nc amplitude and latency, I conducted analyses that were identical to the N290 and P400 analyses except that I analyzed the data for midline (Fz, Cz, Pz, Oz) and temporal (T3-T6) electrodes because the infant Nc component is typically recorded at these electrode sites (e.g., de Haan & Nelson, 1997, 1999; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007) and because prominent Nc deflections were recorded at these electrodes.

Because: 1) Nc amplitude is associated with *a priori* familiarity for stimuli presented with equal probability and salient or attention-getting stimuli (e.g., de Haan & Nelson, 1997); 2) averaged and attractive faces are more prototypical than unattractive faces and may thus be perceived as more familiar than unattractive faces; and 3) 6-month-old infants prefer to look longer to attractive and averaged over unattractive faces (Langlois et al, 1987; Rubenstein, Kalakanis & Langlois, 1999), I expected that averaged and attractive faces would elicit significantly *greater* amplitudes than unattractive faces consistent with previous research showing higher Nc amplitudes to preferred faces and very familiar, salient stimuli like the mother's face (e.g., de Haan & Nelson, 1997;

Leppanen, Moulson, Vogel-Farley, & Nelson, 2007). Also, Nc latency differences have rarely been recorded in infant ERP studies, but some more recent studies have found shorter Nc latencies in response to familiar versus novel stimuli (e.g., Bauer, Wiebe, Carver, Waters, & Nelson, 2003; Nelson, Thomas, de Haan, & Wewerka, 1998). Thus, because averaged and attractive faces are perceived as familiar (e.g., Langlois, Roggman, & Musselman, 1994; Rubenstein, Kalakhanis, & Langlois, 1999) and also may engage attentional mechanisms faster than unattractive faces due to their attractiveness and familiarity, I predicted that Nc latencies may be shorter to averaged and attractive versus unattractive faces.

PSW ANALYSES. To determine the effect of attractiveness on the average amplitude of the PSW, I conducted repeated-measures analysis of variance (RMANOVA) with face type (attractive, unattractive, averaged) and electrode as the within-participants variables and participant sex was the between-participants variable for fronto-temporal (T3, T4) and midline (Fz, Cz, Pz, Oz) electrodes. I examined average PSW amplitude for fronto-temporal and midline electrode groups only because differential slow wave responses are typically recorded in these areas in similar face processing tasks (Nelson & Collins, 1991; Nelson et al., 1998; de Haan & Nelson, 1999) and because late-latency slow waves with a positive deflection were recorded at these sites.

Average PSW amplitude is associated with processing of a partially encoded stimulus and a return to baseline activity is associated with processing of a fully encoded stimulus (e.g., Courchesne, Ganz, & Norcia, 1981; de Haan & Nelson, 1997; de Haan & Nelson, 1996, 1999). Therefore, because averaged and attractive faces are more prototypical and thus perceived as more familiar (e.g., Langlois, Roggman, & Musselman, 1994) than less attractive faces, unattractive faces should be processed as partially encoded, more novel stimuli compared to averaged and attractive faces. I predicted that unattractive faces would evoke significantly higher PSW average amplitudes than both averaged and attractive faces suggesting that they are processed as more novel than equally novel averaged and attractive faces.

RESULTS

There were no effects for participant sex in any of the analyses so I collapsed the data across this variable in each analysis. Further, most analyses did not require the Greenhouse-Geisser correction for unequal variances, however, use of the correction is noted for those analyses that required the correction.

Face-Sensitive ERP Components

N290. There were no significant effects for the N290 amplitude analysis. There were significant differences in N290 latencies to averaged, attractive, and unattractive faces at occipital electrodes, but not temporal electrodes. The ANOVA for N290 latency at occipital electrodes resulted in a significant interaction between face type and electrode, F (4, 196) = 5.549, $p < .05$. Planned contrasts indicated that N290 latency was significantly shorter to averaged and attractive compared to unattractive faces at electrode Oz (ps < .05 (1-tailed) (See Figure 6). Therefore, these results provide support for my prediction that averaged and attractive faces are processed more quickly than unattractive faces due to their prototypicality.

Results also showed that there was a significant, positive correlation between N290 latency and amplitude at all electrodes showing the N290 ($r = .246$, $p < .05$). This result indicates that shorter N290 latencies were related to lower N290 amplitudes.

P400. The ANOVA for P400 amplitude resulted in a significant interaction between face type and electrode at temporal electrodes; F (6, 294) = 3.121, $p < .05$. Planned contrasts showed that P400 amplitude was significantly lower to averaged and attractive versus unattractive faces at right temporal electrodes (T4, T6) (all $p < .05$ (1-tailed) (See Figure 7). The ANOVA for the occipital electrode (Oz) resulted in a main effect for face type, F (2, 98) = 3.275, $p < .05$. Planned contrasts showed that P400 amplitude was significantly lower to averaged versus both attractive and unattractive faces (*p*s < .05 (1-tailed) which did not differ from one another (See Figure 8). Together these results provide some support for the prediction that more attractive faces are processed more fluently than less attractive faces as evidence by lower ERP amplitudes.

In addition, there were no significant effects for the P400 latency analysis. There was a significant, negative correlation between P400 latency and amplitude at all electrodes showing the P400 ($r = -.770$, $p < .05$). P400 amplitude and latency were not positively correlated as predicted.

Familiarity-Sensitive ERP Components

NC. There were no significant effects for the Nc amplitude analysis. There were, however, significant effects for the Nc latency analyses for temporal electrodes. The ANOVA for temporal electrodes resulted in a significant interaction between face type and electrode, F (6, 294) = 3.227, $p < .05$. Planned contrasts showed that Nc latency was significantly lower to averaged and attractive versus unattractive faces (*p*s < .05 (1-tailed) at electrode T3 (See Figure 9). These results indicate that more attractive faces engage neural mechanisms associated with processing of a salient or familiar stimulus more quickly than less attractive faces. The ANOVA with the Greenhouse-Geisser correction for unequal variances for midline electrodes revealed no significant effects for Nc latency.

PSW. The ANOVA for average PSW amplitude for fronto-temporal (T3,T4) electrodes resulted in a significant main effect for face type, F (2, 98) = 3.639 , $p < .05$. Planned contrasts indicated that average PSW amplitude was significantly lower to averaged and attractive compared to unattractive faces (See Figure 10). These results support the hypothesis that averaged and attractive faces are perceived as more familiar than equally novel unattractive faces.

DISCUSSION

Face-Sensitive ERP Components

With regard to the question: Are attractive faces processed more fluently than less attractive faces?, results from Experiment 1 demonstrated that: 1) indeed, more attractive faces are processed *more quickly* than less attractive faces for the early-latency, face-sensitive ERP component (N290), 2) more attractive faces require *lower* amounts of neural activity (i.e., amplitude) to be processed as a face by the brain than less attractive faces for the middle-latency, face-sensitive ERP component (P400), and 3) for the early --latency, face-sensitive component only, amplitude and latency are positively correlated, and thus, both likely reflect the perceptual fluency of face processing. These data are the first to provide an index of the time course and magnitude of infant processing of facial attractiveness and prototypicality and suggest that attractive faces may be preferred because they are prototypical and fluently processed.

While the results for the N290 analysis indicated that attractive faces are more fluently processed through shorter *latencies*, the P400 analysis indicated that attractive faces are more fluently processed through lower *amplitudes*. Neither ERP component analysis provided evidence for *both* faster processing (latency) and lower amounts of processing (amplitude) for attractive versus unattractive faces on its own. These findings clearly provide some support for the assertion that more attractive faces are more fluently processed than less attractive faces, but only the combination of results for both face-sensitive components confirms my predictions for differential latencies and amplitudes based on averageness theory.

Familiarity-Sensitive ERP Components

With regard to the question: Are attractive faces processed as familiar compared to less attractive, but equally novel faces?, results showed that: 1) more attractive faces are processed *faster* than less attractive faces for the mid-latency component (Nc) associated with processing of familiar and salient stimuli (e.g., mother's face) and 2) more attractive faces are perceived and processed as *more familiar* than less attractive faces as indicated by lower average amplitudes for the late-latency slow wave (PSW). These PSW findings provide important support and the first electrophysiological evidence for the theory that attractive faces are processed as more familiar than equally novel unattractive faces, and thus, may be preferred due to their familiarity and prototypicality. These data also provide the first converging electrophysiological evidence in support of infants' ability to form cognitive prototypes (e.g., Rubenstein, Kalakhanis, & Langlois, 1999) using electrophysiological methods.

Nc. Although the results for the Nc latency analysis were consistent with the prediction that more attractive faces would elicit shorter latencies due to their familiarity and/or quick engagement of neural mechanisms of obligatory attention due to their attractiveness and familiarity, I did not find Nc amplitude effects as expected. Also, previous findings showing that more attractive faces are perceived as familiar (e.g., Langlois, Roggman, & Musselman, 1994; Rubenstein, Kalakhanis, & Langlois, 1999), the results for the PSW analysis that confirmed the familiarity of attractive faces, and the finding of equivalent of Nc amplitude to averaged, attractive, and unattractive faces are inconsistent with an interpretation of the Nc latency effects as the result of perception of averaged and attractive faces as more *familiar* than unattractive faces.

To explicate, the results for the Nc analysis were contrary to my prediction that Nc amplitude would be higher to more versus less attractive faces. Because the Nc component is associated with processing of highly familiar and salient stimuli, I expected Nc amplitude to be higher to averaged and attractive versus unattractive faces for several reasons. First, because averaged faces are perceived as familiar due to their prototypicality and infants have the ability to form cognitive prototypes of faces (e.g., Rubenstein, Kalakhanis, & Langlois, 1999), they should elicit higher Nc amplitudes like other familiar stimuli. Second, because attractive faces are similar to averaged faces (e.g., Bronstad and Langlois, 2006), they should elicit higher Nc amplitudes similar to previous research on modulation of Nc amplitude by stimulus familiarity (e.g., de Haan & Nelson, 1997). Third, because infants have visual preferences for averaged and attractive over unattractive faces, they should evoke higher Nc amplitudes similar to other highly salient or attention-grabbing stimuli (e.g., mother's face).

Given that Nc has been associated with processing of familiar and salient stimuli, the lack of Nc amplitude effects suggests that the averaged, attractive, and unattractive faces that infants saw in Experiment 1 were perceived as *equally* familiar and/or salient. The *PSW* results that indicated infants processed the averaged and attractive face stimuli as familiar and unattractive stimuli as novel raise doubts, however, about the functional significance and interpretation of the Nc amplitude results as suggesting that the three types of faces were perceived as *equally familiar*. It is possible, however, that averaged, attractive, and unattractive faces were processed as *equally salient*, but may have been salient or elicited infants' attention for different reasons. Indeed, the Nc has been interpreted as reflective of attentional processing or an obligatory-attentional response, like orienting to a stimulus (e.g., de Haan & Nelson, 1997, 1999). Correspondingly, the infant literature makes clear that many different stimulus features (e.g., complexity, novelty) elicit young infants' visual attention (e.g., Cohen, DeLoache, & Strauss, 1979; Fantz, Fagan, & Miranda, 1975; Easterbrook, Kisilevsky, Hains, & Muir, 1999). See Colombo, (2001) for a review of the infant visual attention literature.

So, though 6-month-olds show robust visual preferences for attractive faces (e.g., e.g., Langlois, Roggman, Casey, & Ritter, 1987; Langlois, Ritter, Roggman, & Vaughn, 1991; Samuels & Ewy, 1985) and this finding has been replicated several times, unattractive faces in Experiment 1 may have been as salient and attention-grabbing as more attractive faces because of their atypical appearance and deviation from a prototypical or averaged face. A wealth of research in the infant literature shows that visual stimuli may elicit infant attention and interest for a variety of reasons and that infant attention to and interest in familiar versus novel stimuli varies according to a variety of factors including age, experience with the stimulus or stimulus class, and stimulus complexity (e.g., Hunter & Ames, 1988).

It is certainly possible that Nc activity was evoked earlier by averaged and attractive faces due to their attractiveness and familiarity as a result of their prototypicality, but that an equal amount of neural activity that presented as Nc was elicited by unattractive faces because of their novelty (e.g., Colombo, 2001; Hunter & Ames, 1988;) or visual pop-out effects (for a review see Rovee-Collier, Bhatt, & Chazin, 1996) in response to distinctive facial features due to their deviation from the average facial configuration. Because stimulus complexity has often been shown to affect stimulus orienting and attract infant visual attention (e.g., Cohen, DeLoache, & Rissman, 1975; Courage, Reynolds, & Richards, 2006; Hunter & Ames, 1988), it is also possible that unattractive faces evoked Nc amplitudes equal to those in response to averaged and attractive faces because unattractive faces are more complex than attractive faces because they are atypical in appearance.

With regard to interpretation of the Nc effects in Experiment 1, it is important to note that the previous research showing infant visual preferences for averaged and attractive faces (e.g., Langlois, Roggman, Casey, & Ritter, 1987; Rubenstein, Kalakhanis, & Langlois, 1999), utilized an infant visual preference paradigm that involves the *simultaneous* presentation of pairs of stimuli (e.g., attractive face, unattractive face). Infant attentional responses and interest in faces varying in attractiveness or prototypicality has rarely been investigated through the serial presentation of facial stimuli one at a time, thus it is entirely possible that the individual rather than paired presentation of averaged, attractive, and unattractive faces in this experiment allowed infants to respond to the three face types with equal Nc amplitudes, but that this activity was evoked in response to different characteristics of the stimuli (e.g., familiarity, novelty, complexity). Nevertheless, given that Experiment 1 was the first and only known infant ERP study of processing of facial attractiveness and prototypicality, future research should be conducted to replicate the findings for the Nc analysis and in order to further investigate and interpret differences in Nc latency and amplitude elicited by averaged, attractive, unattractive faces.

PSW. Compared to the results for the Nc analysis, results from the second analysis designed to determine the effects of facial attractiveness and prototypicality on ERP components modulated by familiarity were uncomplicated. Results for the PSW analysis showed that averaged and attractive faces were processed as more familiar than equally novel unattractive faces. This finding suggested that more attractive faces are, in fact, perceived as familiar compared to less attractive faces due to their prototypicality and are consistent with the predictions of averageness theory and previous research (e.g., Langlois, Roggman, & Musselman, 1994; Rubenstein, Kalakhanis, & Langlois, 1999). This finding not only supports the assertion that attractive faces are prototypical and perceived as more familiar than less attractive, less prototypical faces, but also supports the explanation that more attractive faces are preferred because they fluently processed because stimulus familiarity and fluency are often highly correlated and familiarity contributes to perceptual fluency (e.g., Winkielman, Schwarz, & Nowak, 2002).

Chapter 3:

Experiment 2

Because Experiment 1 was the first electrophysiological test of averageness theory in infants and because it is important to replicate the findings of Halit, de Haan, and Johnson (2000) for N170 amplitude and determine the degree of concordance for differential processing of facial attractiveness between infants and adults, I designed Experiment 2 as a replication of the face-sensitive ERP investigation from Experiment 1 with adults. The results of Experiment 2 are significant because they provide an important replication test of Halit, de Haan, and Johnson's (2000) findings and additional data to aid in the interpretation of the N290 and P400 results and fluency effects related to processing of facial attractiveness and prototypicality in Experiment 1. Thus, in Experiment 2 I measured adults' face-sensitive ERPs to the same averaged, attractive, and unattractive faces that infants saw in Experiment 1. The purpose of Experiment 2 was to determine whether averaged and attractive faces are processed more fluently than unattractive faces as predicted by averageness theory. If so, the adult, face-sensitive N170 component should show lower amplitudes and shorter latencies for averaged and attractive versus unattractive faces, suggesting that more attractive faces are more fluently processed as faces by the brain as evidenced by lower amounts of neural firing and faster processing speed.

METHOD

Participants

Participants were forty-four introductory psychology students (23 female, 21 male, mean age = 19.51 years). An additional 14 participants were tested, but their data were excluded for the following reasons: currently taking mood-altering medications (6), experimenter error (2), failure to follow instructions (1), equipment error (2), neurological disorder (2), and sensory impairment (1). Power analyses indicated that the final sample size was large enough to detect group differences if present (power $\geq$ .80). The majority of participants were Caucasian (59.0% Caucasian, 22.7% Asian Pacific Islander, 4.6%, Hispanic, 2.3% African-American, 4.6% two or more races, and 6.8% unknown).

Stimuli

Stimuli were the same faces used in Experiment 1.

Procedure

The procedure was identical to the procedure in Experiment 1 except that participants sat in a chair placed in front of the computer monitor. As in Experiment 1, two independent observers, blind to the stimuli, coded visual attention of each participant from video tapes made of the participant's face and eyes. Reliability was high (alpha = .99).

DATA ANALYSIS

The recording parameters, waveform averaging procedure, and comparisons of interest for Experiment 2 were identical to those in Experiment 1. Also like Experiment 1, following the creation of grand averaged waveforms for averaged, attractive, and unattractive faces, I conducted repeated-measures analysis of variance (RMANOVA) to determine the effect of attractiveness and prototypicality on ERP waveform latency and peak amplitude. I conducted analyses for the face-sensitive N170 ERP component (See Figure 3 for an example of the N170 ERP component). Participants completed an average of 1373 trials. Although the average number of trials completed by adults in Experiment 2 was much higher than the average number of trials completed by infants in Experiment 1, comparison of results for infants versus adults is not problematic, and, in fact, quite typical in the ERP literature because though infants produce a smaller number of artifact free trials, their ERPs are usually significantly higher in amplitude than adult ERPs (De Boer, Scott, & Nelson, 2004).

I used a standard 120ms-200ms time window to identify the N170 ERP waveform. I identified peak amplitude of the component by determining the highest voltage in the N170 time window. I identified peak latency by determining the time point at which the peak occurred. I conducted separate ANOVAs for the N170 component for the two dependent variables (latency, amplitude).

I conducted separate RMANOVAs to determine the effect of attractiveness on magnitude (N170 amplitude) and speed of processing (N170 latency) for temporal electrodes. Face type (attractive, unattractive, averaged) and electrode (T3, T4, T5, T6) were the within-participants variables and participant sex was the between-participants variable. I included temporal electrodes in the analyses because the N170 component is typically recorded at these specific sites (e.g., Allison, Puce, Perez & McCarthy, 1996; Bentin & Deouell, 2000; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007) and because these electrodes showed a prominent N170 peak in the specified time window. Also, although the N170 component is not typically prominent at midline electrodes, I conducted an additional analysis for a midline electrode group (Fz, FCz, Cz, CPz, Pz, Oz) because these electrodes showed a clear N170 deflection in the specified time window.

Like the infant N290 and P400 components, N170 is a face-sensitive component. If unattractive faces are less prototypical than averaged and attractive faces, they should require more effortful processing to be recognized and processed as a face by the brain. Additionally, Halit, de Haan, and Johnson (2000) previously found that the N170 is modulated by facial attractiveness and prototypicality and recorded higher N170 amplitudes to unattractive versus attractive faces. Therefore, I expected that unattractive faces would elicit significantly higher amplitudes and longer latencies than both attractive and averaged faces. I also calculated the correlation between adults' mean amplitude and latency for the N170 component. If perceptual fluency in face processing is reflected by both shorter latencies and smaller amplitudes, then N170 amplitude and latency should be positively correlated.

RESULTS

There were no effects for participant gender in any of the analyses so I collapsed the data across this variable in each analysis. As in Experiment 1, I note the analyses that required the Greenhouse-Geisser correction for unequal variances.

N170 AMPLITUDE. Like the N290 amplitude analysis in Experiment 1, there were no significant N170 amplitude effects that included face type. The ANOVA for temporal electrodes resulted in a significant main effect for electrode, however, *F* (3, 129) = 62.05, *p* < .05. N170 amplitude was greater at electrode T3 compared to electrodes T4, T5, and T6 and greater at electrode T4 than electrodes T5 and T6 (all *p*s < .05). These results indicate that N170 amplitudes were higher for temporal electrodes over anterior versus posterior scalp regions. There were no effects for the ANOVA with the Greenhouse-Geisser correction for unequal variances for the midline electrode group.

N170 LATENCY. There were significant differences in N170 latencies to averaged, attractive, and unattractive faces at temporal, but not midline electrodes. The ANOVA for N170 latency at temporal electrodes resulted in a significant main effect for face type, *F* (2, 86) = 10.71*, p* < .05. Planned contrasts indicated that N170 latency was significantly shorter to averaged and attractive compared to unattractive faces at temporal electrodes (all *p* < .05 (1-tailed) (See Figure 11). These results provide support for the prediction that averaged and attractive faces are processed more quickly than unattractive faces due to their prototypicality.

CORRELATION BETWEEN N170 AMPLITUDE AND LATENCY. Similar to the infant N290 component, results showed a significant, positive correlation between N170 latency and amplitude at all electrodes showing the N170 (*r* = .592, *p* < .05) suggesting that shorter N170 latencies are associated with lower N170 amplitudes.

DISCUSSION

With regard to the question: Are attractive faces processed more fluently than less attractive faces?, results from this study showed that: 1) attractive faces are processed *more quickly* than less attractive faces for the early-latency, face-sensitive ERP component (N170), but did not elicit lower amounts of processing (i.e., amplitude) than less attractive faces, and 2) N170 amplitude and latency are positively correlated.

The finding that N170 latencies were shorter to averaged and attractive versus unattractive faces is consistent with averageness theory, the prediction that attractive faces are processed fluently because they are prototypical, the results for the infant N290 face-sensitive component, and numerous ERP studies that show longer latencies to less "face-like" and atypical stimuli (e.g., Rossion et al., 2000; Bentin, Allison, Puce, Perez, & McCarthy, 1996; Itier & Taylor, 2004a; Jemel, George, Chaby, Fiori, & Renault, 1999; Rossion & Gauthier, 2002). The lack of differences in N170 amplitude to averaged, attractive, and unattractive faces is consistent with the results for the infant N290 analysis, but inconsistent with my predictions, the findings of Halit, de Haan, and Johnson (2000), and many studies in the ERP literature that show higher N170 amplitudes to less "face-like" stimuli.

Though Halit, de Haan, and Johnson (2000) predicted shorter N170 latencies to attractive versus unattractive faces, they did not record differential latencies to attractive versus unattractive faces. The results for the N170 latency analysis in Experiment 2, however, did indicate shorter latencies to averaged and attractive versus unattractive faces. This finding of shorter N170 latencies to more versus less attractive faces supports the assertion that attractive faces are fluently processed due to their prototypicality.

Indeed, attractive faces may be preferred because they are prototypical, and thus more fluently processed. This finding is significant because when it is combined with the results for face-sensitive infant ERPs in Experiment 1, it supports the assertion that attractive faces are preferred because they are prototypical and fluently processed in accord with averageness theory.

With regard to the differences between the results of Experiment 2 and the results of Halit, de Haan, and Johnson's (2000) study, one explanation for the presence of attractiveness-linked latency effects for N170 in Experiment 2, but lack of effects in Halit, de Haan, and Johnson's (2000) study is that the stimuli used in the two studies differed in two important ways. First, Experiment 2 included averaged faces, whereas Halit, de Haan, and Johnson's (2000) study did not. Second, the attractiveness ratings for the attractive and unattractive faces used in Halit, de Haan, and Johnson's (2000) study suggest that the contrast in attractiveness between the two face types was not particularly large. Thus, Experiment 2 may have been more sensitive to differential processing of facial attractiveness and prototypicality as evidenced by N170 latency because a broader range of facial attractiveness was represented by the stimuli and the differences between the attractiveness of more and less attractive stimuli were larger. Finally, and most important, the sample size tested in Halit, de Haan, and Johnson's (2000) study was small (n = 12) as compared to the sample I tested in Experiment 2, and thus the difference in sample size may have accounted for differences in results between the studies.

Similarly, the differences in results for the N170 amplitude analysis between Experiment 2 and Halit, de Haan, & Johnson (2000) may be due to a number of factors. The presence of predicted N170 effects in Halit, de Haan, and Johnson's (2000) study, but lack of amplitude effects in Experiment 2 may also have resulted from differences in sample size, stimuli, and/or the result of differences in recording methodology (recording parameters (Halit, de Haan, and Johnson, 2000 did not report impedance values), and high versus low density recording methodology) as well as the electrodes of interest examined in the analyses. Thus, a number of methodological differences between Experiment 2 and Halit, de Haan, and Johnson's (2000) study could explain the differences in results between the two studies. Replication studies that utilize sufficiently large samples, and match the recoding methodologies and analytical approaches of the present experiment and Halit, de Haan, and Johnson's (2000) study are necessary for a clearer and more complete analysis of the differences between the two studies and N170 amplitude and latency effects based on facial attractiveness.

In sum, like the results of the analyses for face-sensitive components in Experiment 1, the results for the N170 analysis in Experiment 2 provide support for the theory that attractive faces are preferred because they are prototypical and fluently processed. These findings, particularly when combined with the findings of shorter latencies and lower amplitudes for infant, face-sensitive ERPs to more versus less attractive faces and results for face-sensitive ERPs suggesting that attractive faces are processed as familiar in Experiment 1, provide significant support to averageness theory. Additionally, some of the results differed from those of the only other existing study conducted to determine whether facial attractiveness modulates the face-sensitive N170 component, however, it is likely that the differences are due to the small sample size used in the previous study and a number of methodological differences.

Chapter Four:

General Discussion

The purpose of these experiments was to determine if attractive faces are prototypical and "face-like" and, thus, more fluently processed and familiar than less attractive faces. Taken together, the results of these studies suggest that attractive faces are prototypical and more fluently processed than less attractive faces. Consistent with averageness theory, the results of Experiments 1 and 2 support the assertion that attractive faces are preferred because they are prototypical and fluently processed (e.g., Hoss, Ramsey, Griffin & Langlois, 2005; Langlois & Roggman, 1990; Langlois, Roggman, & Musselman, 1994; Rosen, Griffin, Hoss, Bronstad, & Langlois, 2005). Although these experiments provide support for averageness theory, the results of Experiment 1 (infants) and Experiment 2 (adults) were not wholly uniform. Findings for analyses for face-sensitive ERP components in infants suggested that attractive faces are more fluently processed than less attractive faces as evidenced by shorter *latencies* to attractive faces for one face-sensitive component (N290) and lower *amplitudes* for the other face-sensitive component (P400). Adults in Experiment 2 showed shorter *latencies* to attractive faces for the face-sensitive N170 component. Though each of these findings is consistent with my predictions based on averageness theory, the similarities and differences in results for Experiment 1 versus 2 merit consideration with regard to the study analyses and development and interpretation of ERP components.

CONSISTENCY AMONG THE RESULTS AND DEVELOPMENT OF ERP COMPONENTS

For the N290 face-sensitive component, infants' latencies were significantly shorter to averaged and attractive versus unattractive faces. Likewise, N170 latencies were shorter to more versus less attractive faces. Both findings support the theory that attractive faces are more prototypical and, thus, more fluently processed than less attractive, less prototypical faces. Results for the face-sensitive P400 component in infants indicated lower amplitudes to average and attractive versus unattractive faces, but no significant latency effects, however. This result is in contrast to the null findings for N170 amplitude in adults in Experiment 2. The results for the N290 analysis, but not the P400 analysis in infants were consistent with the results for the N170 analysis in adults. In short, both infants and adults processed attractive faces more fluently than unattractive faces, but the fluent processing of attractive faces was reflected in shorter latencies for some components and lower amplitudes for other components.

Why should results that support averageness and perceptual fluency theories differ among the two face-sensitive infant ERP components? One reason that the results for N290 (infant) included no *amplitude* effects is that the amplitude effects at midline electrodes were close to significance, however, the Greenhouse-Geisser correction for unequal variances was required for the analysis of the midline electrode data and the effect was not large enough to reach significance. It is possible that infant data with equal variances at midline leads would indicate an amplitude effect at N290. It is also possible that analyses of N290 data recorded at electrode sites other than those examined in Experiment 1 may show amplitude effects in addition to latency effects. Although ERP components are traditionally analyzed at specific electrodes (e.g., temporal electrodes) that have been found to show a prominent peak in brain activity at those specific sites across many studies (e.g., de Boer, Scott, & Nelson, 2004), the ERP literature is not without exceptions to these standard approaches. With regard to the lack of *latency* effects for the P400 (infant) as compared to N290 (infant), it is generally unclear why I found no latency effects for P400. These differences require replication and further investigation and may be related to the status of P400 as a developmental precursor to the adult N170 component. Next, I will consider this issue along with the correspondence between the results for the N290 (infant) and P400 (infant) versus N170 (adult) analyses.

Why should results that support averageness and perceptual fluency theories differ among infants and adults? One explanation is that the infant N290 is the lone developmental precursor of the adult N170 component. If so, then the consistency between the N290 (infant) and N170 (adult) findings, but inconsistency between the findings for the P400 (infant) and N170 (adult) is not surprising. Though there is disagreement over whether the N290, P400, or both, are developmental precursors of N170 (see Csibra, Kushnerenko, & Grossmann, in press; de Haan & Nelson, 1997; de Haan, Pascalis, & Johnson, 2002; Halit, de Haan, & Johnson, 2003; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007), a number of groups have recently argued for the N290 as the sole developmental precursor of the N170 (see Csibra, Kushnerenko, & Grossmann, in press). The N290 has been suggested as the better candidate precursor for several reasons: 1) N290 and N170 are both early-latency components whereas P400 is a mid-latency component; 2) N290 and N170 have a characteristic negative deflection, but P400 has a positive deflection; 3) by 12-months, infants’ N290 shows increased amplitude to inverted faces, similar to N170; and 4) N290 shows increased amplitude to faces versus matched visual noise like the N170 (e.g., Csibra, Kushnerenko, & Grossmann, in press; Halit, Csibra, Volein, & Johnson, 2004).

Additionally, the lack of amplitude effects for N170 may be due to the fact that adult ERP component amplitudes are much lower than those recorded in infants and, thus, amplitude effects are often smaller in magnitude in adults versus infants (e.g., de Boer, Scott, & Nelson, 2004). Also, as previously discussed, differential processing of facial attractiveness may not be strongly reflected in N170 amplitude as the only existing study of the effects of facial attractiveness on adult ERPs (Halit, de Haan, & Johnson, 2000) found amplitude effects using a small sample size (n = 12). In contrast, the sample size that I used in Experiment 2 was much larger (n = 44). Finally, like the infant N290, is it also possible that N170 amplitude effects might be recorded at alternate, non-traditional electrode sites not included in the present analyses.

AVERAGENESS THEORY

Even though the results of Experiments 1 and 2 were not completely consistent, the general pattern of results and confirmation of several hypotheses based on averageness theory are remarkable. Most of the analyses of infant and adult ERPs supported the theory that attractive faces are prototypical, “face-like”, and fluently processed as compared to less attractive faces. The results of both experiments along with the finding that fluent processing evokes positive affect (e.g., Winkielman, Schwarz, & Nowak, 2002) provide significant support for the hypothesis that attractive face are preferred because they are prototypical and, thus, fluently processed. The findings from Experiment 1 in particular are notable because they are the first that I am aware of that show that *infants* process more attractive faces fluently as compared to unattractive faces.

With regard to the existing attractiveness literature, these findings both extend and complement previous findings and provide important converging evidence for behavioral data that indicate that averaged and attractive faces are prototypical and familiar (e.g. Langlois & Roggman, 1990; Langlois, Roggman, & Musselman, 1994; Rubenstein, Kalakhanis, & Langlois, 1999). The results of Experiments 1 and 2 also converge with previous reaction time studies showing that attractiveness facilitates the speed and accuracy of face classification by adults and children (Hoss, Ramsey, Griffin & Langlois, 2005; Rosen, Griffin, Hoss, Bronstad, & Langlois, 2005), while providing a more direct measure of processing fluency during very early stages of face processing well before a behavioral response (e.g., reaction time study button press) can be observed. And, most important, these experiments, when coupled with previous tests of averageness theory that used looking time, reaction time, and other behavioral measures, provide compelling evidence that basic information-processing mechanisms play a significant role in facial attractiveness preferences and that these mechanisms are active very early in development.

PERCEPTUAL FLUENCY AND ATTRACTIVENESS PREFERENCES

Although these studies were not designed to test the link between processing ease and affect, the findings raise important questions that are relevant to fluency theories and research on perceptual fluency. The finding that the latencies and amplitudes of the face-sensitive N290 (infant) and N170 (adult) components were positively correlated suggests that fluent processing of faces may be reflected by both shorter latencies (speed of processing) and lower amplitudes (magnitude of processing). I did not find significant differences in *both* ERP component amplitude and latency for the N290 and N170 analyses, however. In some cases results suggested that facial attractiveness facilitated face processing as evidence by latency, but not amplitude, and in others the reverse was true. What, then, is perceptual fluency, and what dependent measures function as an index of perceptual fluency?

While operational definitions of perceptual fluency vary widely in the literature (for a review see Winkielman, Schwarz, Fazendeiro, & Reber, 2003), conceptual definitions of perceptual fluency vary little. In fact, most psychologists as well as researchers in other fields (e.g., business, communications) simply define perceptual fluency as ease of processing. Such a broad conceptualization of fluency has of course produced quite a broad literature composed of studies that vary a great deal in their methods, including the experimental task (e.g., recognition memory, categorization) and independent (e.g., figure-ground contrast, stimulus duration) and dependent variables (e.g., reaction time, naming accuracy).

For the purposes of my research on processing of facial attractiveness and prototypicality, I defined perceptual fluency as ease of processing as reflected by shorter latency and lower amplitude in face-sensitive ERP components based on previous findings in the face perception and neuroimaging literature. Given the effects of attractiveness and prototypicality on both amplitude and latency for face-sensitive ERP components across Experiments 1 and 2 and the positive correlations that I found between these two dependent measures, I believe that perceptual fluency presents as both speed (e.g., latency) and amount of processing (e.g., ERP amplitude) and that both of these dependent measures and features of information-processing define perceptual fluency. That said, the lack of positive findings for both face-sensitive ERP latencies and amplitudes for each face-sensitive ERP component in these experiments combined with the variability in operationalization of fluency in the literature underscores the need for additional research and debate regarding the conception and measurement of processing fluency.

Another important question raised by the findings of Experiments 1 and 2 is: What role does familiarity play in perceptual fluency and preferences? Results for the face-sensitive ERP component analyses in both experiments suggested that attractive faces are prototypical, and, thus, more fluently processed. Results for the PSW analysis of infants' ERPs in Experiment 1 showed that averaged and attractive faces are also processed as more *familiar* than equally novel unattractive faces due to their prototypicality. These findings are consistent with previous behavioral data that showed that adults and infants perceive attractive faces as familiar (e.g., Langlois, Roggman, and Musselman, 1994; Rubenstein, Kalakhanis, & Langlois, 1999). And, prototypicality, familiarity and fluency are often highly correlated and familiarity contributes to perceptual fluency (e.g., Winkielman, Schwarz, & Nowak, 2002). It is clear, therefore, that familiarity may play a role in processing fluency and resulting preferences, particularly preferences for attractive faces. The role and relative importance of stimulus familiarity to processing fluency and associated positive affect and preferences, however, remains unclear in the context of the present findings and extant research on perceptual fluency.

Winkielman and colleagues maintain, however, that though familiarity influences perceptual fluency, it is not necessary for the production of fluency-based preferences. They note, for example, that processing fluency can be enhanced by basic perceptual manipulations (e.g., figure-ground contrast) and that positive affective responses result from the fluent processing of geometric patterns and that these effects hold even for novel and unfamiliar stimuli (e.g., Winkielman, Schwarz, Fazendeiro, & Reber, 2003).

With regard to attractiveness preferences, it is possible that the role and relative impact of stimulus familiarity and perceptual fluency on preferences differ for infants and adults and across development. For example, much of the research in the infant literature has shown that young infants often exhibit strong familiarity preferences for visual stimuli as evidenced by looking longer to a familiar versus novel stimulus (e.g., Bushnell, 2001; Hunter & Ames, 1988; Leinbach & Fagot, 1993; Quinn, Yahr, & Kuhn, 2002). Of course, without concurrent measures of affect (e.g., emotion coding, EMG), it is unclear whether longer looking to one stimulus over another reflects adult-like preferences or liking for a stimulus. In addition, however, very young infants show greater positive affect in response to familiar people (e.g., Fogel, 1980) and around 6-months, infants begin to show clear behavioral preferences for their primary caregivers (e.g., Bowlby, 1969/1982; Marvin & Britner, 1999). Therefore, some developmentalists might argue that familiarity preferences, in the form of experienced familiarity, play a primary role in the development of infant attractiveness preferences. It seems clear that familiarity plays an important role in infants' preferences for attractive faces whether the result of positive affect associated with the conscious experience and perception of familiarity, fluent processing of prototypical faces that is influenced by early, unconscious processing of facial prototypicality and familiarity, or both. And, of course, because unconscious, early-stage information-processing can affect processing at later, more cognitive stages of information processing, it is likely that the familiarity-linked perceptual fluency is related to the conscious experience of stimulus familiarity under many circumstances.

Future research with infants and older children that incorporates concurrent behavioral and physiological measures of processing fluency and affect along with novel stimuli may help clarify the relative importance and roles of experienced familiarity and processing fluency in driving preferences, concordance between objective and subjective processing fluency, and the boundary conditions of perceptual fluency effects. Regardless of the answers that future research provides to these questions, the results of Experiment 1 make a compelling case for the fluent processing of attractive and prototypical faces by infants during very early stages of perceptual processing, and thus the role of perceptual fluency in driving their preferences for attractive faces. These results highlight the important role that early-stage information processing mechanisms can play in affective responses and behavioral preferences as early as infancy.

STEREOTYPE FORMATION

The significance of findings from these experiments is not limited to the attractiveness, infant, or ERP literature. Rather, the findings have broader implications for research on stereotyping, social perception, and attitude change. While it is often assumed that cultural socialization plays a large role in the development of stereotypes, the findings of these experiments along with findings from other recent infant studies make clear that basic processing mechanisms that underlie the development of attractiveness stereotypes are present and active before the end of the first year of life. The results of Experiment 1 suggest that 6-month-old infants process attractive faces more fluently than unattractive faces. Thus, positive affective responses associated with the fluent processing of attractive faces may be present much earlier than previously assumed. More importantly, these early affective responses may serve as the foundation for infant visual preferences for attractive faces seen as early as 2-3 months (e.g., Langlois, Roggman, Casey, & Ritter, 1987), and *social* preferences for attractive over unattractive people observed at 12 months (Langlois, Roggman, & Rieser-Danner, 1990).

More recent studies have shown that by 12months, infants associate pleasant voices, smiling schematic faces, and animated shapes performing positive behaviors with attractive faces. Likewise, 12-month-olds associate unpleasant voices, frowning schematic faces, and animated shapes performing negative behaviors with unattractive faces (Griffin et al., 2007). Furthermore, Rosen & Langlois (2007) showed that 12-month-olds have the ability to learn correlations between facial attractiveness and valence and generalize these associations to novel stimuli. These findings coincide with previous research that demonstrates that 12-month-olds possess the ability and propensity to evaluate and act upon assumptions regarding facial attractiveness (Langlois, Roggman, & Rieser-Danner, 1990). Thus, infants may associate valence with their existing attractiveness preferences by the end of the first year of life and possess the rudiments of fully-developed attractiveness stereotypes that link positive characteristics (e.g., nice) to attractive people and negative characteristics to unattractive people (e.g., mean).

Together these findings from these studies of young infants suggest that basic elements and mechanisms of attractiveness stereotypes are present well before socialization alone can impact stereotype development. Yet, relatively little attention or research has been devoted to investigating the developmental precursors and mechanisms of preferences and stereotypes in very young children. The present findings and recent research on 12-month-olds emphasize the significance and utility of developmental investigations of stereotype development and emphasize the need for similar investigations of mechanisms of attitude and stereotype formation to expand the stereotyping literature and provide a more comprehensive understanding the nature of stereotype formation.

In addition, the results of the ERP analyses in Experiment 1 in particular underscore the automatic nature of processing mechanisms that are functional in *infancy* and may cascade into attractiveness preferences, stereotypes, and attractiveness-based differential treatment with development. Such a finding supports and extends existing studies in the adult social psychology literature that indicate that a variety of attitudes, stereotypes, and feelings are largely the result of automatic processes (e.g., Bargh & Williams, 2006) and, thus, difficult to alter. Accordingly, the findings of Experiments 1 and 2 raise doubts about the effectiveness of interventions designed to ameliorate the negative effects of attractiveness stereotypes by changing attractiveness attitudes and reducing attractiveness stereotyping.

With regard to the present research and attractiveness stereotypes, it seems likely that the only potentially effective intervention for attractiveness preferences and stereotypes is to increase conscious awareness of the effects of fluency on preferences. In fact, previous research has shown that alerting participants to fluent processing as the source of their positive evaluations of stimuli eliminates fluency effects (Winkielman, Schwarz, Fazendeiro, & Reber, 2003). Unfortunately, the long term effectiveness of such effects outside of a laboratory setting is dubious. Also, though Experiment 1 provided clear evidence of fluency effects in infants, interventions designed to reduce the harmful effects of attractiveness stereotypes could realistically only be conducted with pre-school aged children, several years after fluency-based facial attractiveness preferences develop.

Nevertheless, with regard to intervention efforts and attitude change, it is both important and essential to understand the nature of the basic mechanisms that underlie attractiveness preferences and stereotypes. The basic knowledge that attractiveness attitudes and stereotypes may be especially robust and highly resistant to change due to the very early development of automatic processes that underlie attractiveness preferences may result in interventions designed to simply increase awareness of attractiveness stereotyping and its automatic nature. Effects of such interventions are likely to be small, but given the evidence that the rudiments and mechanisms underlying attractiveness preferences, attitudes, and stereotypes develop extremely early in development, they are both worthwhile and significant to consider.

LIMITATIONS OF THE RESEARCH AND FUTURE DIRECTIONS

There are a number of limitations of this research that should be noted. First, because Experiment 1 was the first-ever electrophysiological test of the predictions of averageness theory in infants and because collecting ERP data from infants is very time consuming, I measured ERPs only and did not collect measures of infant behavior or affect. Thus, future replications of these experiments would benefit from the addition of behavioral measures or a multi-method (e.g., looking time, ERP, EMG) approach to aid in the interpretation of the ERP results and provide converging evidence. The incorporation of emotion coding and physiological measures of affect (i.e., EMG) for both adult and infant participants would also allow for the addition of a direct test of the link between processing fluency and positive affect.

In addition, I only used images of Caucasian, female faces in this study. Thus future replications using male faces and faces of other races are necessary. I also limited my investigation to 6-month-olds in Experiment 1. Examination of a wider range of ages could provide significant, additional information about the development of face-sensitive and other infant ERP components and their modulation by facial attractiveness and prototypicality. Previous ERP research has also indicated effects of experience on face processing so measurement and analysis of individual differences in infants' and adults' experience and familiarity with different types of faces may provide additional insight regarding the functional significance of face- and familiarity-sensitive ERP components in infants and adults, as well as the effects of different types of familiarity (e.g., *apriori* familiarity due to experience or cognitive averaging, stimulus repetition) and prototypicality on processing fluency and preferences.

Further, future investigations that utilize additional dependent measures of the time course of face processing including the onset, latency to peak, duration, and rise time of ERP components would provide more detailed illustrations of the time course of processing of facial attractiveness and prototypicality and tests of averageness and fluency theories. Finally, though I followed standard practices for analyzing ERP data collected from participants in this research, including exclusion of the data of participants with missing data at specific electrodes or too few artifact-free trials, future investigations would benefit from the use of more sophisticated statistical analyses and techniques for retaining and analyzing data from participants with missing data points. Much potentially valuable information is lost from data collected in ERP studies of adults and especially infants. In most ERP studies, data from participants with incomplete data go unanalyzed. Thus, innovative analyses that can accommodate missing data and statistical techniques that are sufficient to deal with the complexity and variability of ERP data should be studied and used in future investigations.

Chapter Five:

Conclusions

Two studies, one with infants and one with adults, provided some support for the assertion that averaged and attractive faces are processed more fluently than unattractive faces and are perceived as familiar, as predicted by averageness theory. Infant participants processed attractive faces faster than unattractive faces. Processing of attractive faces as faces by the brain required lower amounts of neural firing compared with unattractive faces. Infants also perceived attractive faces as more familiar than equally novel unattractive faces. In addition, adult participants processed attractive faces faster than unattractive faces. These findings are consistent with the view that the ubiquitous preferences that exist for attractive faces exist because of positive affect evoked by the fluent processing of attractive faces as a result of their prototypicality. The results of these studies also suggest that children's and adults' preferences for attractive faces cannot be attributed solely to socialization and that basic information-processing mechanisms can account for attractiveness preferences even very early in development.

Tables and Figures

Table 1. Infant and Adult ERP Components Relevant to an Electrophysiological Test of Averageness Theory

Component	*Description*	*Associated processes*	*References*
N290 (infant)	120-336ms latency; occipito-temporal topography	• early structural encoding of faces •possible developmental precursor to the adult N170	de Haan & Nelson , 1999; de Haan, Johnson, & Halit, 2003; de Haan, Pascalis, & Johnson, 2002; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007
P400 (infant)	296-460ms latency; occipito-temporal topography	• early structural encoding of faces •possible developmental precursor to the adult N170 • affected by stimulus inversion, but for a broader class of faces (i.e., human and monkey faces) than the adult N170 up to about 12-months of age	de Haan & Nelson , 1999; de Haan, Johnson, & Halit, 2003; de Haan, Pascalis, & Johnson, 2002; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007
Nc (infant)	400 and 800ms latency	• obligatory or automatic attention • thought to reflect features of recognition • affected by stimulus familiarity • sensitive to stimulus probability • most robust infant ERP component; can be observed on single trials	Ackles & Cook, 1998; Bauer, Wiebe, Carver, Waters, & Nelson, 2003; Courchesne, 1977; 1978; 1981; Courchesne, Ganz, & Norcia, 1981; de Haan, Johnson, & Halit, 2003; de Haan & Nelson, 1997; de Haan & Nelson, 1999; Karrer & Monti, 1995; Nikkel & Karrer, 1994; Nelson & de Haan, 1996; Nelson & Monk, 1999; Nelson, Thomas, de Haan, & Wewerka, 1998; Richards, 2003; Snyder, Webb, & Nelson, 2003; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007
PSW (infant)	Late latency slow wave 800 and 1700ms latency	• updating of working memory for a partially encoded stimulus or context information • amplitude decreases across multiple presentations of the same stimulus • returns to baseline following repeated presentation of a stimulus	Ackles & Cook, 1998; Courchesne, 1977, 1978; Courchesne, Ganz, & Norcia, 1981; de Haan & Nelson, 1997; de Haan & Nelson , 1999; Nelson & de Haan, 1996; Nelson & Monk, 1999; Richards, 2003; Snyder, Webb, & Nelson, 2003
Return to baseline (infant)	800-1700ms latency	• stimulus that is fully encoded following various ERP components • associated with stimuli that do not require memory updating and are not perceived as novel	de Haan & Nelson, 1997; Gunnar & Nelson, 1994; Nelson & Monk, 1999
N170 (adult)	170-336ms latency; occipito-temporal topography	• early structural encoding of faces • modulated by familiarity and expertise •affected by face inversion	Batty & Taylor, 2003; Bentin, Allison, & Puce, 1996; Bentin, Allison, Puce, Perez & McCarthy; Bentin & Deouell, 2000; Botzel & Grusser, 1989; Caharel, Poiroux, & Bernard, 2002; Caldara, Thut, & Servoir, 2003; Campanella, Hanoteau, & Depy, 2000; Campanella, Quinet, & Bruyer; 2002; Carmel & Bentin, 2002; Cauquil, Edmonds, & Taylor, 2000; de Haan, Pascalis, & Johnson, 2002; Eimer, 2000a; Eimer, 2000b; Eimer, Holmes, & McGlone, 2003; George, Evans, Fiori, Davidoff, & Renault, 1996; Goffaux, Gauthier, & Rossion, 2003; Guillaume & Tiberghien, 2001; Halit, de Haan, & Johnson, 2000; Henderson, McCulloch, & Herbert, 2003; Hertz, Porjesz, Begleiter & Charlion, 1994; Jemel, Pisani, & Calabria, 2003; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007 Mouchetant-Rostaing & Giard, 2003; Rebai, Poiroux, & Bernard, 2001; Rossion, Delvenne, & Debatisse, 1999; Rossion, Gauthier, Tarr, Despland, Bruyer, Linotte, &Crommelinck, 2000; Sagiv & Bentin, 2001; Sagiv & Shlomo, 2001; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002; Schweinberger, Pickering, & Jentzsch, 2002; Yovel & Levy, 2003

Table 2. ERP Terminology

Term	*Definition*
Component	A deflection of the electrical response of the brain elicited by a stimulus or event thought to reflect specific cognitive processes and information within the cortex that is recorded at the scalp
Slow wave	A deflection of the electrical response of the brain elicited by a stimulus or event thought to reflect more diffuse neural activation that typically shows no noticeable peak
Baseline	Level of brain activity (microvolts) recorded prior to the presentation of a stimulus commonly used to define ERP components and slow waves
Amplitude	A measure of ERP component magnitude determined by subtracting the peak value of the component (microvolts) from the value of baseline (microvolts)
Peak	Highest amplitude value of an ERP component relative to baseline
Latency	A measure of ERP component and slow wave timing determined by recording the time at which peak amplitude occurs post-stimulus onset (milliseconds)
Topography	Pattern of distribution of neural activation across the scalp typically described by electrode location
Average amplitude	Mean amplitude score (microvolts) calculated for slow waves showing no noticeable peak
Impedance	A measure of total opposition to the flow of electrical current
Low density (ERP) recording	Measurement of scalp-recorded ERPs using a small (3-8) to moderate number (12-40) of electrodes placed according to the 10-20 recording system
High density (ERP) recording	Measurement of scalp-recorded ERPs using a larger number (64-256) of electrodes at non-traditional recording sites for the purpose of localization of the neural signal

Table 3. Study Predictions by Component Waveform

Component	Latency Prediction	Rationale	Amplitude Prediction	Rationale
N290 (infant)	Averaged and attractive faces will show significantly shorter latencies than unattractive faces	● Averaged and attractive faces are more prototypical than unattractive faces	Greater to unattractive as compared to attractive and averaged faces	● N-290 is face-sensitive ● Unattractive faces are less prototypical than averaged and attractive faces and, thus, should require more effortful processing to be recognized and processed as a face by the brain
P400 (infant)	Averaged and attractive faces will show significantly shorter latencies than unattractive faces	● Averaged and attractive faces are more prototypical than unattractive faces	Greater to unattractive as compared to attractive and averaged faces	● P400 is face-sensitive ● Unattractive faces are less prototypical than averaged and attractive faces and, thus, should require more effortful processing to be recognized and processed as a face by the brain
Nc (infant)	Averaged and attractive faces will show significantly shorter latencies than unattractive faces	● More attractive faces are prototypical and thus perceived as more familiar than less attractive faces and engage familiarity processing or attentional mechanisms rapidly ●Consistent with previous findings for familiar versus novel stimuli (e.g., Nelson, Thomas, de Haan, & Wewerka, 1998)	Greater to averaged and attractive as compared to unattractive faces	● Nc amplitude is associated with *a priori* familiarity for stimuli presented with equal probability and salient or attention-getting stimuli ●Averaged and attractive faces are more prototypical than unattractive faces and may thus be perceived as more familiar than unattractive faces ●Six-month-old infants have visual preferences for attractive over unattractive faces. ●Attractive faces elicit greater attention and are more familiar than less attractive faces, and thus should evoke responses consistent with previous research showing higher Nc amplitudes to preferred faces and very familiar stimuli like the mother's face (e.g., de Haan & Nelson, 1997)
PSW (infant)	No latency predictions	● Late-latency slow waves are not analyzed for latency because they do not show a clear peak in amplitude	Significantly greater to unattractive as compared to attractive and averaged faces	● PSW average amplitude is associated with processing a partially encoded, relatively novel stimulus ●More attractive faces are prototypical and thus perceived as more familiar than less attractive faces ●Unattractive faces are less prototypical and should therefore be processed as novel stimuli compared to averaged and attractive faces
N170 (adult)	Averaged and attractive faces will show significantly shorter latencies than unattractive faces	● Averaged and attractive faces are more prototypical than unattractive faces	Greater to unattractive versus attractive and averaged faces	● N170 is face-sensitive ● Unattractive faces are less prototypical than averaged and attractive faces and, thus, should require more effortful processing to be recognized and processed as a face by the brain ● Consistent with the findings of Halit, de Haan, & Johnson (2000)

Figure 1. ERP Topography Illustrated by 10-20 System Recording Region.

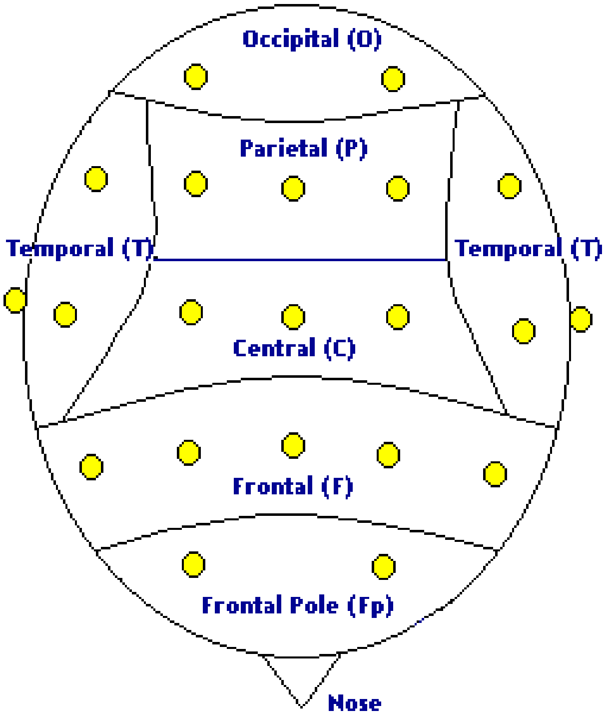


Figure 2. ERP Topography Illustrated by Electrode Location.

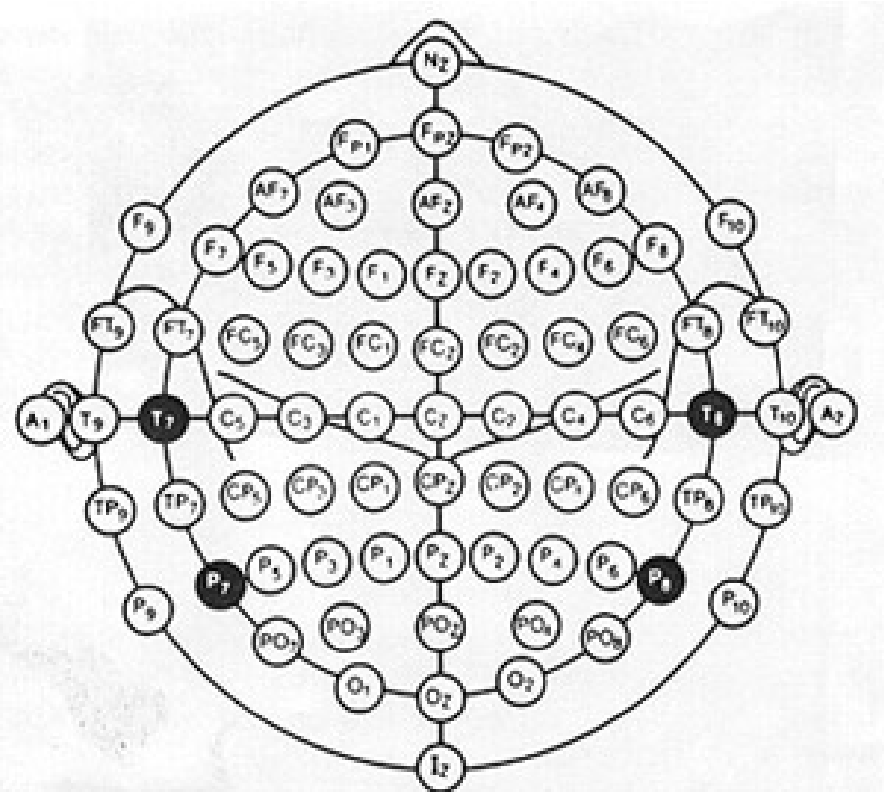


Figure 3. Adult N170 ERP Component.

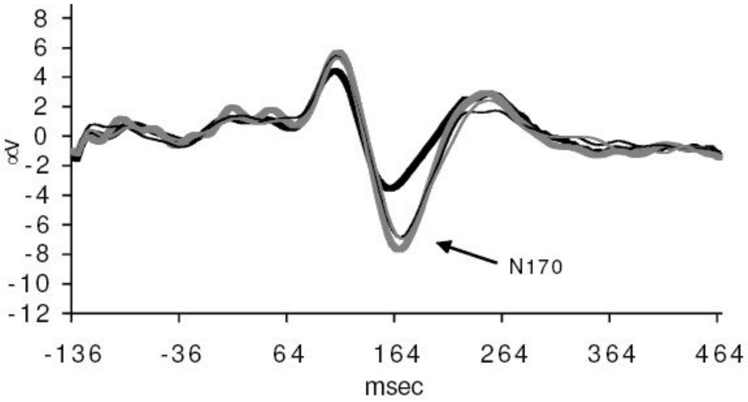


Figure 4. Infant N290 and P400 ERP Components.

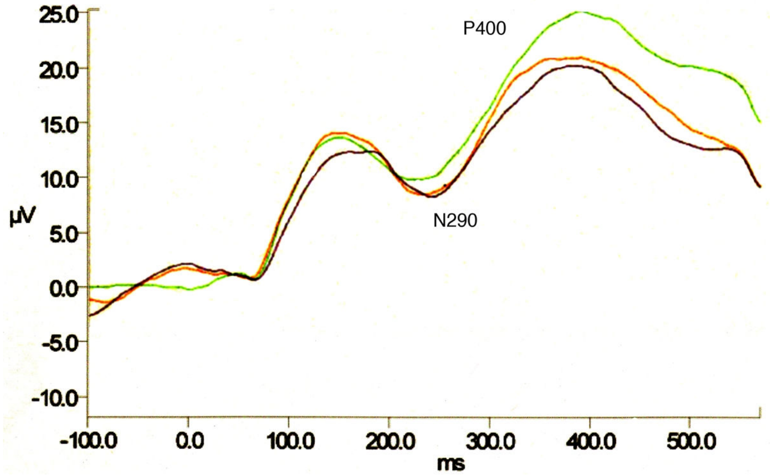


Figure 5. Infant Nc and PSW ERP Components.

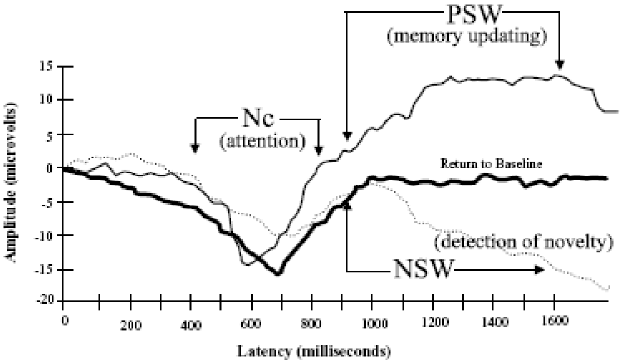


Figure 6. Mean N290 Latency to Averaged, Attractive, and Unattractive Faces at Oz.

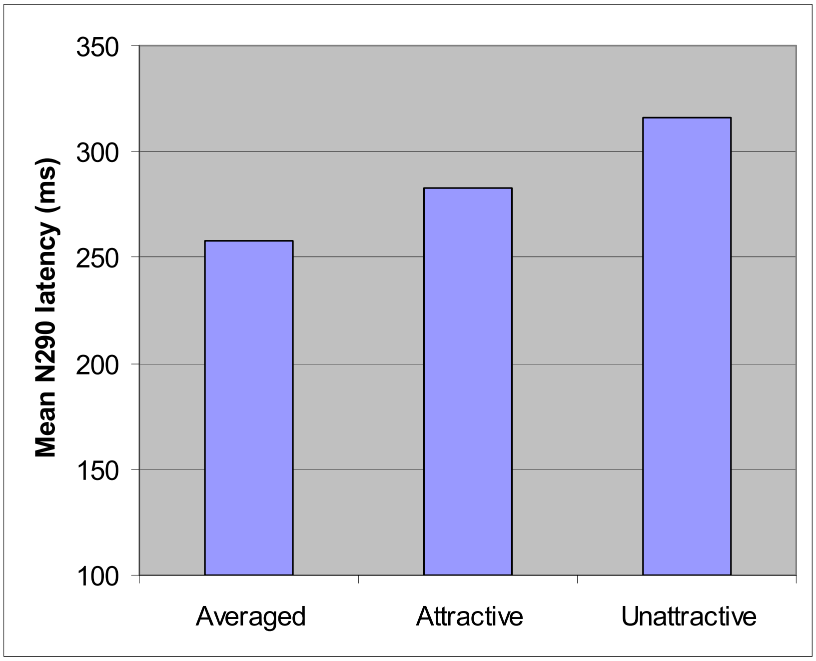


Figure 7. Mean P400 Amplitude to Averaged, Attractive, and Unattractive Faces at Right Temporal Electrodes.

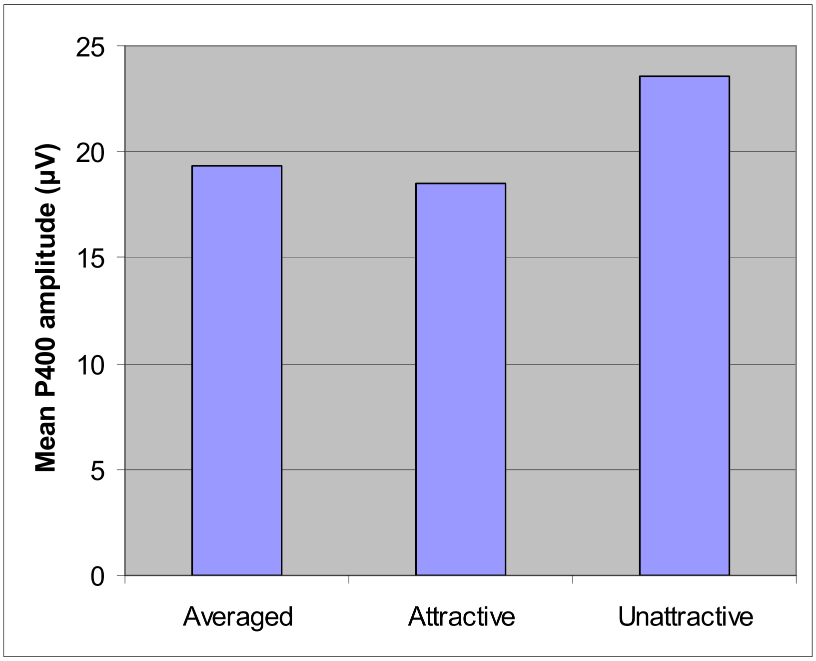


Figure 8. Mean P400 Amplitude to Averaged, Attractive, and Unattractive Faces at Oz.

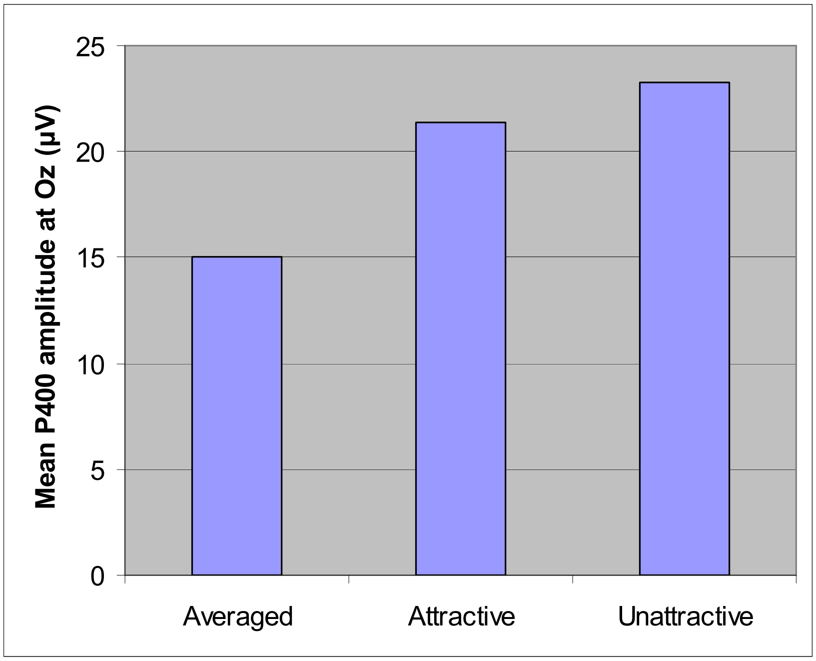


Figure 9. Mean Nc Latency to Averaged, Attractive, and Unattractive Faces at T3.

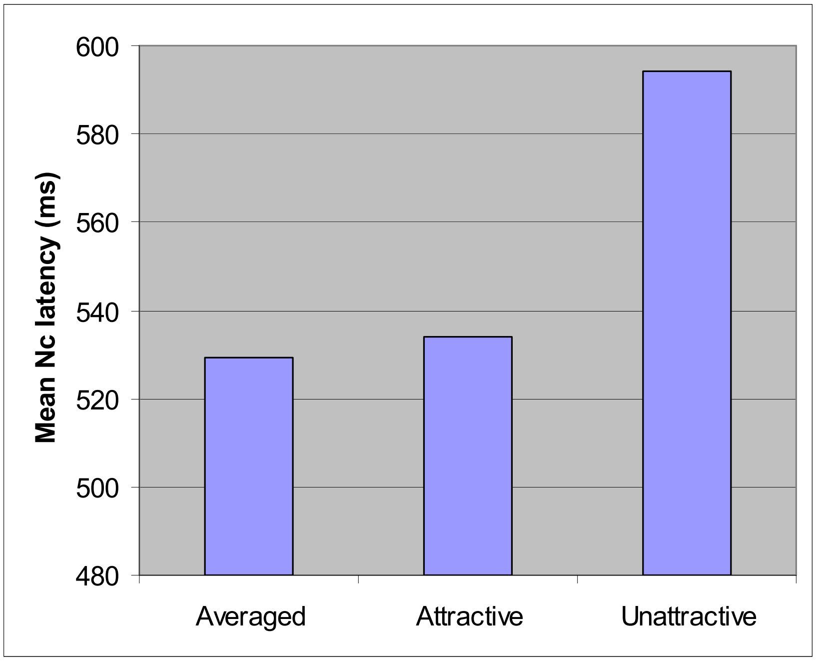


Figure 10. Mean Average PSW Amplitude to Averaged, Attractive, and Unattractive Faces at Frontotemporal Electrodes.

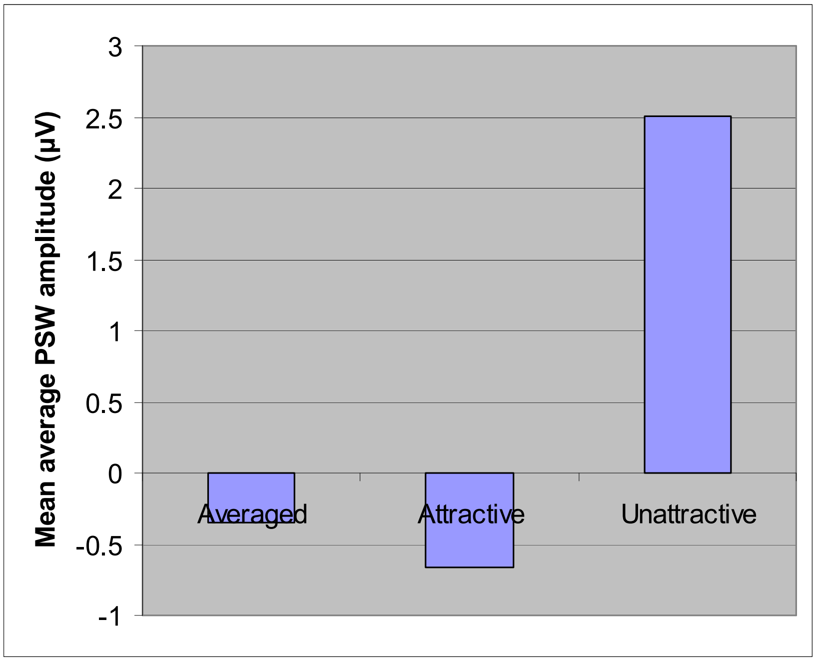
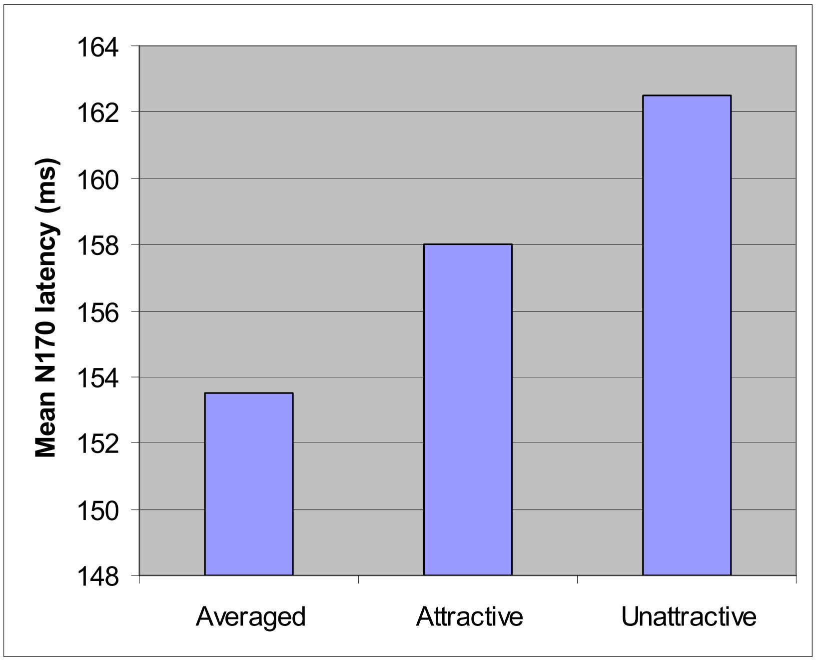


Figure 11. Mean N170 Latency to Averaged, Attractive, and Unattractive Faces at Temporal Electrodes.



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