PUBERTY MATTERS: A LOOK AT THE DEVELOPMENT OF FACE RECOGNITION BIASES IN CHILDREN AND ADOLESCENTS

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ABSTRACT

It is impossible to encode every face that we encounter with sufficient detail for later recognition. As a result, an individuals’ perceptual system becomes tuned over the course of their lifetime to recognize particular faces. For example, adults exhibit biases such that they show superior recognition abilities for faces belonging to particular categories (e.g. race, species, age, gender) of faces. The own-age bias (OAB) is one such bias and is reflected in better recognition of similar aged faces. The literature investigating this phenomenon in children and adolescents is sparse and inconclusive at best. The present study examined the independent contributions of age and puberty to the formation of the OAB as children, adolescents, and adults recognize male and female faces. In so doing, this study specifically tested predictions from a novel theory that emphasizes the role of age-appropriate social developmental tasks in shaping face processing behavior, including the OAB, particularly during adolescence and pubertal development (Scherf, Behrmann, & Dahl, 2012; Scherf & Scott, 2012). Consistent with the theory, prepubescent children (ages 6-8 yrs) did not exhibit an OAB, but instead showed a recognition bias in favor of adult female faces. Adolescents in the early stages of pubertal development did not exhibit any consistent biases in recognition behavior, indicating a potential disruption in the pattern of biases with the onset of gonadarche. Age-matched adolescents in later stages of gonadarche evinced an own-sex bias regardless of the age of the faces they were observing, which was similar to the adult pattern of bias. This study represents a novel contribution to understanding the impact of pubertal development in the formation of biases in face recognition behavior during the course of human adolescence.
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Chapter 1

Introduction

In order to recognize an individual face, we must extract its invariant structural characteristics in spite of the immense variation of circumstances in which we encounter the face (e.g., differences in lighting, context, viewpoint). This is an immense undertaking for the visual system, especially given that humans may recognize hundreds or even thousands of different faces. As such, the visual system does not have the resources necessary to encode all faces encountered in all contexts in the level of detail necessary for subsequent recognition. In other words, it is impossible to have equal representational capacity for all faces. As a result, the perceptual system becomes tuned over the course of an individual's lifetime to recognize the faces that they encounter most often. For example, adults often exhibit strong biases in face recognition abilities such that they show superior recognition abilities for faces belonging to particular categories that are largely over-represented in their experiences. One such bias is the own-age bias (OAB), which has been observed in middle-aged adults and is reflected in better recognition of similar-aged adult faces compared to both adult faces from older age groups and child faces (Anastasi & Rhodes, 2005, 2006; Ebner & Johnson, 2009; Hills & Lewis, 2011; Wright & Stroud, 2002). Another bias is reflected in superior recognition of faces from one’s own gender (i.e., the own gender bias, OGB, Lewin & Herlitz, 2002). Understanding how these biases in face recognition abilities emerge and potentially fluctuate throughout development can provide critical insight into the mechanisms by which perceptual tuning occurs. Moreover, examining biases in face recognition is a means to understanding perceptual learning and how it is influenced by critical changes over time as a function of developmental processes and environmental influences. As such, the present study sought to explore the developmental course
and processes involved in the emergence of age- and gender-related biases (i.e., the own-age bias [OAB], the own-gender bias [OGB]) in face recognition abilities.

**Current and Competing Theoretical Frameworks**

The most prominent theories about the role of experience in shaping the ability to represent and encode faces, and thus bias face recognition, include the Social Cognitive Theories (SCTs; for review see Hugenberg, 2010). These theories generally argue that a primary component of face processing involves categorizing faces into an in-group or out-group (Sporer, 2001). Under this framework, the depth of processing required for faces depends upon their relevance to the individual. That is, out-group faces are not processed as thoroughly as in-group faces because they are not as relevant as faces deemed to be part of one’s in-group. As a result, individuals are predicted to be better at individuating faces perceived as part of their in-group. For example, adults exhibit superior recognition and discrimination for same-race faces compared to other-race faces (the own-race bias), suggesting the notion of an in-group/out-group effect on the basis of race membership (Hugenberg, Young, Bernstein, & Sacco, 2010). Conversely, out-group faces do not engage the same perceptual processes as in-group faces, which makes them more difficult to discriminate and recognize. Unfortunately, in-group/out-group hypotheses are difficult to formulate and evaluate when considering that an individual’s in-group may fluctuate frequently as one progresses through development and be highly context-dependent. In this way, SCTs may be an overly parsimonious account of a set of behaviors that are likely to be dynamically changing across context and development.

More specifically, the Contact Theory (Sporer, 2001), the foundation of SCTs, argues that only faces that have been categorized as part of one’s in-group are then perceptually and cognitively processed with holistic and configural strategies that are necessary for individuation
and, thus recognition. In contrast, faces of people categorized as part of one’s out-group are never processed with these critical strategies and, therefore, cannot be individuated. As a result, individuals become less proficient at discriminating between out-group faces due to a lack of experience. In so doing, faces belonging to an out-group are pushed farther away from prototypical face within one’s representational “face space” and are thus subject to less fine-tuned scrutinizing. Importantly, Contact Hypotheses maintain that faces from the out-group can eventually lead to a change in their status such that they begin to engage the processes and strategies similarly used for the recognition of in-group faces. In other words, the more experience one has with out-group faces, the more one’s representational space will shift to incorporate such faces. For example, the widely studied own-race effect has been suggested to stabilize around age 3 but is extremely flexible even into adulthood. Importantly, the own-race bias is only subject to malleability with intense exposure and practice individuating faces from a less familiar race (Lebrecht, Pierce, Tarr, & Tanaka, 2009; McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011; Xiao, Quinn, Pascalis, & Lee, 2014). Some variation of the Contact Hypotheses and SCTs are used jointly to inform studies of face processing biases.

While SCTs have long stood as the leading conceptualization of biases in face recognition, they are also problematic in several ways: 1) SCTs do not make clear predictions about what motivates individuals to constitute a face as belonging to their in-group or an out-group 2) SCTs do not delineate the potential effects of particular kinds of exposure with respect to modulating face recognition biases, 3) Contrary to an expanding literature, SCTs predict that simple exposure suffices to instantiate biases 4) Above all, SCTs do not offer any predictions about how in-groups may change as a function of development. Here, I will highlight the ways in which SCTs conceptualize biases and how they arrive at particular predictions within this framework. In describing this framework, I hope to demonstrate the ways that it is insufficient in
explaining the OAB phenomena and why there is a need for a new framework for the OAB in the literature.

According to SCTs, there are numerous characteristics that may constitute an in-group or out-group category (e.g. species, gender, race, age), making it difficult to parse which characteristics are most relevant in any given circumstance. For example, SCTs would predict that infants will exhibit superior recognition for other human faces over other-species’ faces (e.g., monkeys), due to extensive contact with humans fostering in-group/out-group categorizations. Contrary to these predictions, existing findings demonstrate that infants do not evince superior recognition for human faces at 6-months of age (Pascalis, de Haan, & Nelson, 2002). In terms of experience, the SCTs emphasize that the way in which some faces are over-represented in one’s environment may serve as a proxy for who is in one’s in-group as opposed to an out-group. Yet, Pascalis and colleagues’ findings are in direct conflict with these SCT hypotheses given that human faces are over-represented in infants’ environment from birth and infants presumably have minimal to no contact with monkey faces. These findings reflect that there are developmental mechanisms at play that cannot necessarily be explained by SCTs.

There is currently some contention in the literature regarding whether social cognitive theories’ (SCT) competing hypotheses of cumulative, life time exposure or most recent exposure can best account for the properties of face perception that lead to the emergence of faces biases, like the OAB. For example, if most recent experience is the primary factor, then an adult high school teacher might have superior recognition for faces of adolescents (who may or may not be considered part of their “in-group”). In contrast, if lifetime experience is the primary influence in shaping one’s representational space for faces, the teacher may exhibit comparable recognition abilities for both adolescent and adult faces. Though these two hypotheses are currently the preeminent conceptualizations of the OAB, existing evidence is at odds with both theoretical assumptions. For instance, previous work has found that neonatal nurses are better at
discriminating between infant faces compared to other adults with less infant-specific experience (Cassia, Picozzi, Kuefner, & Casati, 2009). Likewise, preschool teachers as well as teacher trainees exhibit recognition biases for children’s faces of a similar age to the students they interact with daily compared to those who do not interact with children on a regular basis (Harrison & Hole, 2009; Kuefner, Cassia, Picozzi, & Bricolo, 2008). These findings indicate that biases may primarily reflect the characteristics of faces that are over-represented in one’s immediate environment, regardless of social categorization. In other words, adults are expected to primarily assign in-group status to other adult faces, though these findings challenge this notion by demonstrating that assumptions of social categorization can be broken down by experience. In cases where there are several groups of faces that are overrepresented in one’s environment, biases can be stratified on the basis of experience. For example, recent work has shown that young children demonstrate strong age-related biases toward adult faces and those with older siblings have equally robust biases for adult and child faces (Cassia, Pisacane, & Gava, 2012). Thus, it is clear that SCTs fail to differentiate between the effects of most recent exposure or cumulative (lifetime) exposure with respect to modulating face recognition biases. Furthermore, it is especially difficult to dissociate these two predictions in adult populations given that adult faces are likely to be the age group we are all most consistently exposed to from birth and the most frequently encountered in most adults’ environments.

Another core issue with SCTs is the notion that simple exposure is sufficient to motivate biases in face recognition behavior. For example, some work has shown that biases in face recognition can actually be induced when artificial in-group categories are imposed upon participants (while race is held constant across stimuli and participants) (Bernstein, Young, & Hugenberg, 2007). However, it is unclear how lasting these biases are and if they are replicable outside of laboratory settings. Importantly, other work has consistently demonstrated that a critical component of face-recognition bias development lies not only in the exposure, but also in
the individuation of faces implicated in a particular bias. In the case of the own-race bias, it is only under conditions where individuation of a specific group of faces is required that a bias is imbued (McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011). Furthermore, aside from the influences of different types of experience, what constitutes an in-group versus an out-group is often times ambiguous. It is challenging to conceptualize age as a potential in-group/out-group category, given the current literature. For example, one could predict from this perspective that there would be constant change in the faces that an individual has biases for due to aging. This would likely be untenable to test empirically and does not seem to be consistent with previous findings. In illustration, it is largely supported in the literature that neonates have biases toward adult faces that have similar characteristics to their primary caregiver (e.g. race, gender, age, etc.) (Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). Discrepancies of this nature have yet to be reconciled in the literature.

**Evidence Regarding Social Cognitive Theories**

SCTs argue that face recognition abilities are superior for individuals categorized as part of one’s social “in-group”, but that repeated exposure to individuals initially determined as belonging to an “out-group” may improve recognition abilities for these individuals (Sporer, 2001; Hugenberg, et al., 2010). For example, Korean children growing up in Korea will tend to exhibit an own race bias (e.g., superior recognition for other Korean faces compared to other race faces); however, Korean individuals who are adopted into Caucasian families as infants often develop a race bias for Caucasian faces, not Korean faces (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005). SCTs would argue that because the adopted Korean children had extensive exposure to Caucasian faces, they then became considered their “in-group”. On the
basis of experience and exposure alone, SCTs offer a parsimonious account and set of predictions regarding face-processing biases.

With respect to age biases, the SCTs would predict that similar-aged faces are categorized as belonging to one’s social “in-group”, which contributes to superior recognition abilities for peer-aged faces. In other words, the OAB in adults is thought to reflect more exposure/experience with same-age adult faces. Some findings suggest that adults sometimes show an own-age bias (OAB), which is reflected in better recognition of similar-aged adult faces compared to both adult faces from other age groups and child faces (Anastasi & Rhodes, 2005, 2006; Ebner & Johnson, 2009; Hills & Lewis, 2011; Randall, Tabernik, Aguilera, Anastasi, & Valk, 2012; Wright & Stroud, 2002). For instance, one study reported that irrespective of the nature of the encoding task (i.e., friendliness ratings, attractiveness rating, age estimate, and face search task), young adults were better at recognizing same-age young adult faces (Randall, et al., 2012). Unfortunately, this study only included young adults and no other age groups from which to compare age-related face recognition biases. Despite some reports of an OAB in adults, it does not seem that the literature necessarily supports SCT predictions regarding same-age peer faces always eliciting superior recognition abilities. For instance, infants would be not expected to have biases for other infant faces, given that their exposure to faces is likely disproportionately limited to that of their primary caretaker and not other infants. In fact, literature suggests that infants are more attuned to faces with characteristics similar to that of their primary caretaker (Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995), which is in direct conflict with SCT predictions.

Empirical data from OAB studies are largely mixed, even with respect to adults, who are claimed to provide the strongest evidence thus far for the existence of the OAB. Specifically, findings from the adult literature seem to be conflicting and may be dependent upon the age group tested (e.g., young adults vs. older adults) as well as the paradigm used (Anastasi &
Rhodes, 2006; Ebner & Johnson, 2009; Slessor, Laird, Phillips, Bull, & Filippou, 2010). For example, studies evaluating the existence of age-biases in adults tend to include some combination of younger and older adults, and young children as comparison groups. For instance, Anastasi & Rhodes (2005) tested the face recognition abilities of children (5-8 years old) and older adults (55-89 years old) for same and other age faces (i.e., child, young adult, middle-aged, and older adult faces). Results revealed that the children and adults exhibited age biases toward their own age group. Interestingly, how both groups exhibited OABs seems to have been manifest in different ways; children evinced a response bias through high hit rates for same-age faces but comparable false alarms for all groups while adults seemed to achieve an OAB by way of high hit rates for same-age faces and low false alarm rates for all other aged faces. Though these findings provide some support for SCT predictions, SCTs could not predict this differential pattern of results that appear to be age-dependent.

Other studies have suggested that the existence of age biases depends upon the age of participants and the paradigm being used (e.g., eyewitness paradigms vs. incidental/intentional old/new recognition paradigms). That is, some experiments have shown that young adults demonstrate a stronger OAB than older adults (Slessor, et al., 2010), while other findings suggest the opposite in that middle-aged adults demonstrate the most robust OAB (Anastasi & Rhodes, 2006). It is difficult to interpret these conflicting findings under a SCT framework. Though, based upon a lifetime exposure hypothesis, older adults would be predicted to lack a strong OAB given that they have been in all of the age groups, which would support Slessor and colleagues’ (2010) findings. Unfortunately, the other findings do not seem to provide coherent support for SCT hypotheses, especially when considered together. Some studies have even reported that they do not find evidence for any clear biases for same-age faces in adult groups (Ebner & Johnson, 2009). Together, these findings demonstrate that the current literature is substantially mixed, even for a bias that is purported to be robust in adults. Furthermore, these findings stand in contrast to
the predictions made by SCTs, such that it is not always the case that adults will have the strongest biases for their own age group, if any age-related biases at all.

Finally, the SCTs do not offer clear predictions about how biases in face processing should change developmentally. That is, thus far, studies have only tested whether an OAB exists in adults and young children. Evidence for the presence or absence of age-related biases in children is even less consistent than the adult literature. There have been no systematic attempts to understand how the OAB emerges and changes as a function of time and developmental contexts. That is, findings seem to be limited in so far as studies actually include children and examine this bias from a developmental perspective. More specifically, some studies have demonstrated that children do evince an OAB (Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Goldstein & Chance, 1964; Hills, 2012; Lindholm, 2005), while others show that children show biases toward adult faces (Cassia, Kuefner, Picozzi, & Vescovo, 2009; Cassia, Piscacane, & Gava, 2012; Proietti et al., 2012), or no age-related biases at all (Mondloch, Maurer, & Ahola, 2006). For example, in children as young as 3, there is some evidence for a processing advantage for adult faces (Cassia, Luo, Pisacane, Li, & Lee, 2014). Conversely, other findings suggest that children just 2-3 years older (i.e., ages 4 to 6) evince face memory biases toward their own age group (Anastasi & Rhodes, 2005; Hills, 2012). More specifically, Hills (2012) tested children ages 6-10 for their recognition memory for 8-year old faces in a longitudinal design. In this particular study, an old/new recognition paradigm was used, which tested participants on their memory for 8 year-old faces and 20-22 year-old faces after a brief delay between training and testing. Findings from this study suggest that face processing advantages for one’s own age group adapt rapidly in children, such that 8 year olds can recognize other 8-year-old faces more accurately than when they were 7- and 9-years-old. While these findings appear to be compelling, it is important to note that participants were not tested across time for their recognition accuracy for 6, 7, 9, and 10 year old faces; participants were only tested on their accuracy for 8 year-old
faces, making it difficult to arrive at any firm conclusions on the emergence and continuity of this bias across age. These findings provide support for a most recent exposure account of the OAB such that 8 year-olds become perceptually tuned to same-age faces. Though, as previously mentioned, findings suggesting that children have an OAB are far and few between.

Interestingly, other findings suggest that children’s age-biases are contingent upon their own experience with other children, such that children (ages 3 and 6) with younger siblings will have similar processing abilities for both infant and adult faces (Cassia, et al., 2009; Cassia, Proietti, & Pisacane, 2013). In conjunction with other recent findings (Cassia, et al., 2014), there is some suggestion that children’s representational space may typically be more tuned to adult faces, but that extensive experience with different aged children (especially younger siblings) can temper the robustness of this bias for adult faces. Altogether, findings regarding age-related biases in children seem to be largely mixed with respect to which age groups children have a processing advantage for. In terms of how these findings fit within the popular SCT framework, it is likely the case that SCTs would not be able to predict this pattern of results given that they do not make strong predictions about motivational factors that may impact superior recognition of particular faces other than simply having in-group membership. Moreover, SCTs are unable to make clear predictions regarding how development may induce fluctuations in who is considered one’s in-group and how this may result in particular biases. In the same vein, defining who belongs to one’s in-group would also be dependent upon many factors (e.g., number of group’s one is a member of, certain social characteristics and diversity present within ones environment), which are likely to be dynamic and change as a function of context. Findings such as Cassia and colleagues’ (2009; 2013) provide evidence for the impact motivational processes have upon shaping face recognition biases. In so doing, findings such as these highlight flaws in the inherent simplicity of SCTs. That is, while SCTs give an incredibly parsimonious account of the OAB, they are unable to capture the more nuanced factors that could potentially offer more
comprehensive and accurate accounts of the phenomenon (e.g., developmental and motivational processes involved). In concert with the adult literature, it is an open question whether OABs are present throughout development and to what extent perceptual experience and motivation shape this bias. In addition, the literature thus far has overwhelmingly focused on early and later childhood, which is problematic given the large body of research indicating that face recognition abilities continue to improve through and beyond adolescence (Jüttner, Petters, Wakui, Davidoff, 2014; Lui, et al., 2013; Thomas, De Bellis, Graham, LaBar, 2007). As such, it is imperative that research investigates how and the extent to which these face processing behaviors are being shaped during adolescent development.

**Novel Developmental Task Model**

Recently, Scherf and Scott (2012) provided a new model for conceptualizing biases in face processing. Scherf and Scott propose a model that takes a functionalist perspective on the development of face processing biases, placing special emphasis on the importance of developmental tasks; developmental tasks are age-appropriate abilities that must be mastered in order to adapt to life and continue development in an adaptive manner (Havighurst, 1972). For instance, adolescents’ primary developmental tasks include forging autonomy from parents, forming intimate peer relationships as well as sexual and romantic relationships. Conversely, for children, social developmental tasks are focused on the formation and maintenance of attachment relationships with primary caretakers. This model predicts that developmental tasks (i.e. forming attachment relationships in infancy, establishing romantic and sexual relationships in adolescence), not simply maturation or exposure, present crucial motivational factors that shape one’s representational space for faces and thus influence and sculpt face processing biases. Importantly, this framework postulates that motivation to accomplish age-appropriate social
developmental tasks will influence the types of information individuals need to extract from faces at different developmental points. For example, under this framework, it would be expected that in order to achieve the developmental task of forming a strong attachment relationship with a primary caregiver, infants need to recognize their primary caregivers. Therefore, they need to be able to discriminate and recognize these individuals from other similarly looking individuals (e.g., women or men that look like their mother or father). As a result, the perceptual systems of infants are predicted to be disproportionately tuned to recognize faces that possess the same characteristics (i.e., gender, age, race) of their caregivers. In this way, it can be inferred that infants have recognition biases toward their mothers or fathers, depending upon who is their primary caretaker.

As previously mentioned, empirical work supports this notion such that infants tend to have biases towards faces that have similar characteristics as those of their primary caretakers. For example, infants can recognize their own mothers very early in development and tend to have stronger biases toward female faces, likely due to an overrepresentation of female faces (i.e., mothers) in their initial experiences (Quinn et al., 2010; Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Ramsey-Rennels & Langlois, 2006). It is also the case that infants with fathers as primary caregivers display superior recognition for male faces (Quinn, et al., 2002; Rennels & Simmons, 2008). Critically, Scherf and Scott’s framework argues that infants’ biases for female faces or faces with characteristics of their caretaker is not completely contingent upon experience per se, but that the need to form an attachment relationship with their primary caretaker. Moreover, it is clear that SCTs could not make this prediction, especially when considering that the main mechanism of SCTs is experience, and not motivation for calibrating biases for particular faces. Though there have not been any direct empirical tests of this theory, some of the emerging literature regarding young children supports predictions that would likely stem from Scherf and Scott’s model.
A substantial amount of work has been done to understand infant processing of faces as well as the formation and tuning of biases in infancy (e.g., Cassia, Bulf, Quadrelli, & Proietti, 2014). Other critical points in development, like adolescence, have been less studied and are less understood in terms of the changes that may be occurring in face processing abilities. Furthermore, even less work has been done to understand how developmental tasks may change face-processing behaviors during adolescence. During adolescence, the developmental task of forming strong peer relationships as well as sexual and romantic relationships may instigate qualitative changes in which faces adolescents have superior recognition for. In this way, this potential shift in face processing abilities during this developmental period may lend critical insight into the formation of particular biases (i.e. the OAB). Moreover, understanding this particular trajectory may provide unique understanding about the critical ways in which experience shapes our visuoperceptual and cognitive abilities more generally.

**Evaluating the Developmental Task Model**

More recent approaches argue that pubertal development and age-appropriate developmental tasks (e.g., for adolescents a new desire to evaluate peers as potential romantic and sexual partners) lead to the emergence of an OAB via enhanced discrimination and recognition of peer faces (Scherf & Scott, 2012). Scherf and Scott offer a novel framework that takes developmental motivations into account. Using a more functionalist approach, Scherf and Scott contend that qualitative changes occur in face recognition abilities as a result of developmental transitions in the age-appropriate tasks and goals with which individuals are confronted. According to this framework, influences brought about by developmental tasks can fundamentally change the ways in which individuals scrutinize faces. In reference to the current study - in the advent of pubertal development, peers take on new salience and relevance, which
may influence the way adolescents are motivated to process and recognize peer faces. In other words, pubertal development drives a distinct shift in adolescents’ development of sophisticated social relationships as well as a newfound interest in romantic relationships with peers. These development tasks and demands are the impetus to scrutinize peer faces in an importantly different way than was previously done in development. In order to navigate the social world and ultimately master such developmental tasks, adolescents’ recognition abilities may become more specifically tuned toward same-age peer faces. Conceptualizing the developmental trajectories of face processing abilities in terms of mastery of developmental goals may allow for a more coherent interpretation and explanation of modifications in face processing abilities (i.e. emergence of the OAB).

The present study will evaluate alternative predictions that follow from this new model, which hypothesizes that adolescence is a unique developmental period in which critical transformations in face processing emerge (Scherf, et al., 2012; Scherf & Scott, 2012). Due to the paucity of OAB studies incorporating adolescent age groups, contributions of pubertal development in the increasing salience and relevance of peers during adolescence have yet to be explored. To date, no studies have directly addressed this bias across children, adolescents, and adults. In studying this phenomenon across these age groups, the present study offers an opportunity to evaluate competing hypotheses in the literature as well as pubertal contributions in the functional reorganization of face processing abilities. Thus, I tested the hypothesis that pubertal development, not age per se, leads to re-organization of face processing skills, including the emergence of an OAB. No current version of social cognitive theories would make such a prediction due to the fact that SCTs do not take into consideration the primacy that social developmental tasks bear in the formation of face processing abilities and biases. In addition, SCTs do not provide accounts of or predictions about the potential nonlinearity or discontinuity in
the developmental trajectories of face processing abilities when confronted with such developmental tasks.

In addition to age being a characteristic by which in-group status can be defined, sex is also an important defining characteristic. As was previously mentioned, SCTs do not make predictions about which characteristics (e.g., age, sex, race) may shape biases in a particular context. Conversely, the Development Task Model can make clear predictions about which facial characteristics (e.g., age vs. sex of face) may be critical in shaping recognition biases in particular developmental contexts. For example, while age may be particularly relevant in making predictions about biases for peer faces in adolescence, sex may be especially relevant for children who may be predicted to have biases toward the sex of their primary caretaker (i.e., females, if their mother is their primary caretaker). Given that sex may have different levels of primacy across development, the present study sought to evaluate how this is manifest in face recognition biases. Though the literature regarding biases in recognition of different sex faces is limited, the most robust finding is that women have a processing advantage over men for other female faces (Godard & Fiori, 2010; Hampson, van Anders, & Mullin, 2006; Rehnman & Herlitz, 2006; Lewin & Herlitz, 2002). More specifically, women’s processing advantage is usually in the form of speed and not accuracy (Godard & Fiori, 2010; Hampson, et al., 2006). Few findings have demonstrated that both males and females have an own-sex bias (Shaw & Skolnick, 1994, 1999; Wright & Sladden, 2003), and there are no studies to our knowledge showing that males have superior recognition abilities compared to females.

Little to no literature has explored the intersection of age- and sex-related biases in face recognition and how that is modulated across development. Though some sex bias literature has demonstrated that infants and children attune to female faces (or faces that are most representative of their primary caretaker) (Quinn et al., 2010; Quinn et al., 2002; Ramsey-Rennels & Langlois, 2006; Rennels & Simmons, 2008), the extent to which there are sex differences in
these (or any) face recognition biases has yet to be investigated. Thus, the present study offered a unique opportunity to bridge together these two literatures (i.e., age- and sex-related biases in face recognition) by asking an exploratory research question from a developmental perspective. That is, the present study sought to be one of the first evaluations of whether there are modulations in recognition biases for different sex and aged faces from childhood up to adulthood. Since this was an exploratory investigation, I did not have clear predictions for all groups examined. Though, since peer groups are initially same-sex in early adolescence, it may be predicted that the OAB is initiated toward same-sex peer faces.

In order to systematically evaluate the emergence of potential age- and sex-related biases, I conducted two experiments using the same developmentally-sensitive paradigm. In the first experiment, children (6-8 years) and adults (18-25 years) were tested on whether they evinced an OAB and the extent to which these biases were modulated by the sex of the face being observed. In the second experiment, a group of adolescents (11-14 years) in varying stages of pubertal development were tested for the emergence of an OAB as well as sex-related biases.

**The Present Study**

The present study had three core objectives: 1) to explore the ways in which age and puberty independently contribute to shaping the emergence of biases in face recognition during childhood and adolescence 2) to explore whether there are developmental differences in recognition of different sex faces. I tested the hypotheses from Scherf and Scott's novel framework, which offered an alternative set of predictions about the emergence of an OAB from existing theories. Specifically, I hypothesized that pubertal contributions during adolescence would generate developmental motivations for adolescents to process and recognize peer faces in fundamentally new ways. I predicted that the developmental motivations and tasks involved in
adolescence may result in the emergence of this bias. To our knowledge, there was the first study to directly address this bias across children, adolescents, and adults. Moreover, this was the first empirical investigation to examine the impact of pubertal development on these face recognition biases. In studying this phenomenon across these age groups, the present study offered an opportunity to address empirical questions about the role of experience in manipulating face perception as well as pubertal contributions in the functional reorganization of face processing abilities.

Predictions

Several sets of predictions were proposed for the present study on the basis of immediate experience, lifetime exposure, and a developmental motivations model. Social cognitive theories (SCTs) emphasizing the influence of current experience would predict that participants show superior recognition abilities for faces from their own age group, independent of pubertal status and age. In contrast, SCTs emphasizing the influence of cumulative lifetime exposure would predict that children exhibit a bias for adult faces (since they are most commonly encountered from birth) and potentially for same-age faces as well. Furthermore, adults and adolescents would not exhibit any biases, regardless of pubertal status, because they have previously been exposed to faces from each of these age groups. Our novel theoretical framework predicted that adults would exhibit the strongest biases for other sexually mature adults. Adolescents were predicted to exhibit biases only if they were in the late pubertal group and the biases were predicted to be toward peers that were also more sexually mature. Finally, pre-pubertal children and adolescents in the earliest stages of pubertal development were predicted to have age-related biases toward adults. This novel set of hypotheses were predicated on the notion that developmental tasks and motivations guide whom participants have biases for.
Chapter 2

Method

General Methodology

Participants

Participants in this study were drawn from four developmental groups. The first group included pre-pubertal 6-8 year olds (Tanner stage 1). The second group included 11-14 year adolescents in the early stages of pubertal development (Tanner stages 1-2); the third group included age-matched 11-14 year old adolescents in the later stages of pubertal development (Tanner stages 3-5). The fourth group included sexually mature young adults (ages 18-25 years).

A power analysis was conducted (using the G-Power) in which we assumed a modest effect size (.20) for a within- and between-subjects interaction (development group [4] x condition [4] x sex of participant [2] x sex of stimuli [2]) in a repeated-measures ANOVA. In order to achieve a significance level of $p < .05$, this study was projected to need 72 participants total. To satisfy this criterion, we included 20 participants in each developmental age group with a total of 80 participants. We were able to test a total of 59 adults. A total of 40 children (6-8 years) and 65 adolescents (11-14 years) were tested. Participants came into the lab for a one-time session that lasted approximately 45-60 minutes. This study was embedded in a larger project. The task itself lasted approximately 10 minutes, which was counterbalanced with the other tasks included in data collection for the larger study.
Recruitment

Recruitment of the full sample (including piloting) consisted of a multipronged approach. 1) The majority of the child and adolescent participants were recruited via the Families Interested in Research (FIRst Families) Database. 2) For initial piloting of the experiment, the youngest participants were also recruited via a science-oriented outreach program, Brain Camp, which we developed in collaboration with the Discovery Space children’s museum. Brain Camp is modeled after a program that Jim Tanaka at the University of Victoria designed and successfully implemented to teach children about the science of face processing. Children ages 6 to 8 years attended a half-day camp with a variety of activities (i.e., craft activities, computerized games, etc.) intended to teach and engage the children in the science of face processing and brain awareness. These same children also had the opportunity to participate in the very science they learned about during the camp. 3) Adolescent participants were recruited at a local STEM fair as well as several brain awareness outreach programs targeting local middle and high schools. 4) Lastly, adult participants were recruited through the PSU Psychology Department subject pool.

All participants were pre-screened for psychological, neurological, and endocrinological disorders prior to testing. Individuals indicating any diagnosed concussion or head injury were excluded from the sample. In addition, any participants diagnosed with a psychological or neurological disorder in themselves or their immediate relatives were excluded (i.e. biological mother, father, and full siblings). Specifically, any incidence of Autism Spectrum Disorders, Pervasive Developmental Disorders, Bipolar Disorder, or Schizophrenia in participants’ immediate family were excluded because these disorders are known to affect face processing abilities (Bistricky, Ingram, & Atchley, 2011; Greimel, Schulte-Ruther, Kamp-Becker, Remschmidt, Herpertz-Dahlmann, & Konrad, 2014; Kohler, Hoffmann, Eastman, Healey, & Moberg, 2011). Lastly, any participants indicating extreme complications with their mother’s
pregnancy, birth, or early development (delayed speech, walking, etc.) were excluded from this sample.

Stimuli

The stimuli consisted of 120 gray-scaled photographs of faces with neutral and happy expressions (see Figure 1). Photographs were acquired from the Nimstim (Tottenham, et al., 2009), Karolinska (Lundqvist, Flykt, & Öhman, 1998), and NIMH-ChEFS (Egger, et al., 2011) face databases. In addition, approximately half of the late adolescent group stimuli were taken here at the PSU campus. Images included male and female faces (5 male and 5 female targets) for each block. All images were gray-scaled and presented on a black background. Luminance was standardized across images. Any extreme blemishes or scars were masked so as to eliminate any potential cues to recognition other than facial features. The faces in the stimulus set vary by shape and size, which have not been normalized in order to maintain the naturally occurring variance in faces. Though, the relative ratio of the images were standardized to accommodate screen size (nothing exceeding 400 pixels in height) and to avoid any image becoming more or less salient due to size alone. It is typical in face processing studies with adults for hair and clothing to be masked (e.g., Boothroyd, Meins, Vukovic & Burt, 2014), but for research involving children, there is precedent for including hair and clothing in stimuli images (Saxton, et al., 2010). After substantial piloting with (i.e., unmasked) and without hair and clothing (i.e., masked), I decided to incorporate unmasked stimuli images so as to avoid floor effects in the younger participants’ performance.
Experimental Paradigm

The experiment consisted of a 4 (developmental groups: prepubertal children, early pubertal adolescents, later pubertal adolescents, adults) x 4 (conditions: prepubertal child face, early pubertal adolescent faces, later pubertal adolescent faces, and adult faces) design in which all participants recognized faces of individuals from all development groups. For instance, a participant in the child group had to recognize faces from each of the four developmental groups. Face recognition abilities were measured in an old/new recognition paradigm using a computerized game adapted from a recent study (Ewing, Pellicano, and Rhodes, 2013). As in a classic old/new recognition paradigm, after studying a series of faces, participants identified whether each face in a series of new images is a new or old face.
The task was presented in a blocked design with each block containing face stimuli from a different developmental group (pre-pubescent, adolescent - early pubertal, adolescent - later pubertal, sexually mature adults). The order of the blocks was counterbalanced with each developmental group. Each block was associated with a different, age appropriate movie. Participants first completed a practice phase, which consisted of an abbreviated version of the task. Each task block was divided into three sections, training, delay, and recognition. Before the training phase, participants were encouraged to encode the faces and were notified that they would be tested on the faces later in the game. During the training phase, participants were presented with 10 different target faces; each had a “neutral” expression. Adults and adolescents had 2000 ms to encode each face, whereas the children had 3000 ms. In the delay period, all participants watched a trailer for the movie (approximately 1.5 minutes). In order to provide a quality distraction for the target faces the participants had just seen and would be tested on afterward, the distractor movies for each developmental group were chosen specifically because they had dynamic human faces. After participants watched the brief distractor movie trailer, they were presented with 10 targets and 10 distractors (randomized) for 3000ms each for adults and adolescents and 5000ms for children, all with happy affect. To indicate recognition, participants made a “yes” or “no” (yes = I recognize this face, no = I do not recognize this face) by button press before proceeding to the next trial; see Figure 2. By presenting perceptually transformed images of the target faces (i.e., different affect) during the test phase, we were able to assess participants’ invariant representation of face identity (not memory for the specific image).

Reaction time (RT) as well as accuracy data were collected for each trial. D-prime scores were computed for each condition. Both RT and accuracy were evaluated for and transformed to correct transgressions of normality. Skew values between +/- 1 and kurtosis values between +/- 3 for both RT and accuracy were accepted. We also evaluated whether the variance across all age groups was similar. Importantly, d-prime scores for many participants in the present study were
negative or 0, indicating that d-prime was undefined (i.e., 0; unable to distinguish signal from noise) or that there was sampling error or confusion in the task (Stanislaw & Todorov, 1999). An undefined d-prime can be yielded when hit rate or false alarm rate are either 0 or 1. This presents a large practical problem given that a value of 0 for false alarm rate is quite common and a hit rate of 1 is not an impossibility. As a result, I used A’ as an alternative measure of sensitivity given that it is able to treat signal and noise distributions that are non-parametric (Pollack & Norman, 1964; Zhang & Meuller, 2005).

Experiment 1

The goal of Experiment 1 was to evaluate the extent to which there were age- and sex-related differences in sexually mature adults and pre-pubescent children in age-related biases of face recognition behavior for male and female faces. Given that sex hormones have been found to influence particular types of behavior and their underlying neural architecture (for review, see Blakemore, Burnett, & Dahl, 2010; Feinberg & Campbell, 2010; Forbes & Dahl, 2010; Schulz, Molenda-Figueira, & Sisk, 2009; Spear, 2011; Varlinskaya, Vetter-O’Hagen, & Spear, 2013), we sought to evaluate whether there were any sex differences within and between children and adults in the face recognition behavior. By comparing children and adults in this study, we aimed to create an extreme subjects design whereby if sex differences were evident in this behavior, they
would be most evident in adults and least evident in children. That is, the influence of sex hormones would most apparent in sexually mature adults who have already completed pubertal development. Importantly, there is no strong theoretical grounding for predicting that sex differences would exist in the face processing behavior of interest (as it has been sporadically reported in other face processing behaviors; Godard & Fiori, 2010; Hall, Hutton, & Morgan, 2010; Hampson, et al., 2006; Lewin & Herlitz, 2002). In other words, there were no firm predictions under the current model and, as a result, the first study was exploratory in nature.

**Experiment 1 Method**

**Participants**

Participants included pre-pubertal 6-8 year olds (Tanner stage 1) and adults ages 18-25. A total of 40 children and 59 adults completed the task. Three males and one female were excluded from the final sample of children because their parents rated them as higher than Tanner Stage 1. An additional 5 adults and 5 children were excluded from the present analyses due to below chance performance across all conditions. From the final set of 55 adults, I randomly selected 15 adult females and 15 adult males (M = 19.97, SD = 2.40) to match the final sample of 30 children (15 males; M = 7.33 age, SD = .61). Participants came into the lab for a one-time session that lasted approximately 45 minutes. The task itself lasted approximately 10 minutes.

**Measures**

For the children, pubertal status was assessed in terms of secondary sex characteristics (i.e. breast, phallic, testicular and pubic hair development) via the Tanner staging measure
(Marshall & Tanner, 1968) as well as the Pubertal Development Scale (PDS; Petersen, Crockett, Richards, & Boxer, 1988) through parent report. Parents also reported the last opportunity they had to observe their child naked. Reports of this typically ranged from the day of or prior to testing to a week before testing. Research has demonstrated that acquiring parent report of pubertal status using these measures prior to age 11 is comparable to physician report (Petersen, et al., 1988). Adults did not complete any of the measures of pubertal development on themselves, but were screened for neuroendocrine and developmental abnormalities prior to being enrolled in the study.

**Experimental Paradigm**

Analyses in the present experiment focused on responses to peer-aged faces for the two groups, including only the child and adult faces.

**Results**

Two separate repeated measures were conducted on A’ sensitivity (as a measure of accuracy) and mean correct RT measures. To evaluate the extent to which there were sex differences in accuracy and speed with which children and adults processed different age and sex faces, an omnibus repeated-measures ANOVA was conducted with the within-subject factors of age of stimuli (2: child, adult) and sex of stimuli (2: male, female) and the between-subjects factors of participant age (2: child, adult) and participant sex (2: male, female). Higher-order interactions were investigated by holding between-subjects factors constant in order to investigate lower-level interactions. Finally, simple effects of lower-order interactions were investigated with
t-tests were conducted to evaluate the magnitude of condition and sex differences. There were no violations of sphericity and the groups were comparable in variance across the measures.

A’ Sensitivity

Figure 3 illustrates that both children and adults were more sensitive to recognizing adult faces compared to child faces. There was a main effect of age of stimuli, F(1, 56) = 14.37, \( p = .000, \eta^2_p = .20 \) (refer to Table 1). Across both groups, participants performed better on adult faces (\( M = .76, SE = .02 \)) than on child faces (\( M = .65, SE = .02 \)). In other words, both child and adult participants exhibited a recognition bias toward adult faces. Importantly, this was qualified by a 2-way interaction between the age of the stimuli faces and the age of the participants, F(1, 56) = 3.974, \( p = .05, \eta^2_p = .07 \). Separate paired-samples t-tests within each age group revealed that children were more accurate when recognizing adult faces (\( M = .70, SE = .03 \)) compared to child faces (\( M = .59, SE = .07 \)), \( t(29) = 1.63, p = .04 \). Similarly, adults were also biased to recognize adult faces (\( M = .79, SE = .03 \)) more accurately compared to child faces (\( M = .66, SE = .03 \)), \( t(29) = 3.13, p = .004 \) (See Figure 4). These findings illustrate that both children and adults are better at recognizing adult faces. Interaction effects were likely attributable to adults performing significantly better than children on adult faces, \( t(58) = 2.36, p = .02 \). In contrast, adults and children performed comparably on child faces, \( t(58) = .32, p = .32 \). Importantly, there was no main effect of participant age group, which demonstrates that the developmental modifications that we instituted in the task (i.e., longer encoding and testing time allotted for children) were successful in allowing adults and children to perform at comparable levels.
Notes. Pairwise t-tests significant at p<0.05 level.

Figure 3-1: Overall sensitivity to adult and child faces from experiment 1
Table 1-1: Experiment 1 Repeated Measures ANOVA A’ Sensitivity Results (2x2x2x2: Age of Participants, Participant Sex, Age of Stimuli, Sex of Stimuli).

<table>
<thead>
<tr>
<th>Main Effects</th>
<th>dF</th>
<th>F</th>
<th>p</th>
<th>η²_p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant Sex</td>
<td>1, 56</td>
<td>7.28</td>
<td>0.009</td>
<td>0.115</td>
</tr>
<tr>
<td>Age of Stimuli</td>
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<td>14.37</td>
<td>&lt;.001</td>
<td>0.204</td>
</tr>
<tr>
<td>Sex of Stimuli</td>
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<td>0.651</td>
<td>0.423</td>
<td>0.011</td>
</tr>
<tr>
<td>Age of Participant</td>
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<td>2.30</td>
<td>0.135</td>
<td>0.040</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interactions</th>
<th>dF</th>
<th>F</th>
<th>p</th>
<th>η²_p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant Age x Participant Sex x Sex of Stim</td>
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<td>10.38</td>
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<tr>
<td>Participant Age x Age of Stim</td>
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<td>3.97</td>
<td>0.051</td>
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<tr>
<td>Participant Age x Sex of Stim</td>
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<td>15.95</td>
<td>&lt;.001</td>
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<tr>
<td>Participant Age x Participant Sex x Age of Stim</td>
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<td>0.054</td>
<td>0.817</td>
<td>0.001</td>
</tr>
<tr>
<td>Participant Sex x Age of Stim x Sex of Stim</td>
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<td>0.035</td>
<td>0.852</td>
<td>0.001</td>
</tr>
<tr>
<td>Participant Age x Age of Stim x Sex of Stim</td>
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<td>1.05</td>
<td>0.309</td>
<td>0.018</td>
</tr>
<tr>
<td>Participant Sex x Age of Stim</td>
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<td>0.467</td>
<td>0.010</td>
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<td>Participant Sex x Sex of Stim</td>
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<td>1.03</td>
<td>0.316</td>
<td>0.018</td>
</tr>
<tr>
<td>Part Age x Part Sex x Age of Stim x Sex of Stim</td>
<td>1, 56</td>
<td>0.035</td>
<td>0.309</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Notes. Significant at p<0.05 level.
There was also a main effect of participant sex, $F(1, 56) = 7.283, p = .009, \eta^2_p = .12$; however, this was qualified by a sex of face x age group x sex of participant interaction, $F(1,56) = 10.38, p = .002, \eta^2_p = .16$. There was also a sex of the stimuli faces x participant age group interaction, $F(1, 56) = 15.95, p = .000, \eta^2_p = .22$. To investigate the highest order 3-way interaction, we evaluated lower-order interactions between the sex of the stimuli and the sex of participant within each age group separately. Within the children, a two-tailed $t$-test revealed that they recognized female faces ($M = .73, SE = .02$) more accurately than male faces ($M = .63, SE = .03$), $t(29) = 3.47, p = .002$ (Figure 5a). Next, to explore whether there were sex differences in terms of which faces (female or male) the children had biases for, one-tailed $t$-tests were conducted. Findings showed that female children were trending toward having significantly better recognition for female faces ($M = .74, SE = .03$) compared to male faces ($M = .69, SE = .03$),
$t(29) = 1.74, p = .10$. Conversely, male children exhibited enhanced sensitivity to female faces ($M = .72, SE = .04$) compared to male faces ($M = .58, SE = .05$), $t(14) = 3.13, p = .007$.

In terms of adults, a slightly different pattern of results emerged. A pair-wise two-tailed t-test revealed that adults display higher sensitivity to male faces, $t(29) = 1.79, p = .001$. Upon further parsing, results demonstrated that this effect is likely driven by male adults evincing superior sensitivity to male faces ($M = .75, SE = .03$) compared to female faces ($M = .61, SE = .04$), $t(14) = 3.72, p = .002$. Interestingly, female adults did not perform significantly differently on male ($M = .77, SE = .03$) and female faces ($M = .79, SE = .04$), $t(14) = .48, p = .64$ (Figure 5b). Together, the results from this interaction demonstrated that female children evinced a slight (trending) recognition bias toward female faces while female adults did not evince any sex-related face recognition biases. Conversely, males displayed a strong bias toward female faces during childhood, but this bias shifted toward superior recognition for male faces by emerging adulthood.
Child: Sex by Sex of Stimuli Performance

A.

*Condition A' Sensitivity*

Notes. Pairwise t-tests significant at p<0.05 level.

Figure 5-1: Male and female sensitivity to sex of stimuli graphed as a function of participant age group from experiment 1.
Reaction Time

There was a main effect of sex of the stimuli, $F(1, 56) = 4.20, p = .04, \eta^2_p = .07$) whereby all participants were faster at responding to female faces ($M = 1.33, SE = .06$) compared to male faces ($M = 1.47, SE = .08$) (Figure 6). There were no other main effects or interactions with any other factors.

Notes. Pairwise t-tests significant at $p<0.05$ level.

Figure 6-1: Overall participant speed for male vs. female faces from experiment 1.

Experiment 1 Discussion

Experiment 1 of the present study aimed to evaluate whether there were age-related face recognition biases in children and adults. In addition, this experiment sought to evaluate whether
sex differences contributed to these biases in recognition patterns. Results established that the children and adults demonstrated a bias (i.e., higher A’ sensitivity scores) toward adult faces in terms of recognition ability. It is notable that adults evinced a stronger bias (i.e., superior recognition ability) toward adult faces compared to children. Importantly, these developmental differences are consistent with predictions under the novel theoretical model (Scherf & Scott, 2012) tested here. Moreover, this finding is distinctly inconsistent with some of the predictions that would be made by SCT models of immediate and lifetime experience. Recall, immediate exposure hypotheses would predict that children would have superior recognition for other children their age, given extensive exposure to peer faces in school and other social settings. Lifetime experience hypotheses would predict that children would likely have comparable biases in face recognition for adults and children due to extensive exposure to both age groups in their lifespan. This prediction would have likely resulted in a null effect, whereby children would have exhibited equal recognition accuracy patterns for child and adult faces. Thus, the present study lends support for the notion that developmental tasks have an influential role in shaping the face recognition biases that individuals exhibit. That is, for pre-pubertal children, primary caretakers are arguably the most important figures in their lives. As a result, being able to discriminate and recognize adult faces, particularly adult female faces in this sample, is a critical skill supporting social developmental tasks in childhood, such as attachment formation and maintenance.

Interestingly, all participants were faster at recognizing female faces compared to male faces. In children, regardless of child sex, female faces were recognized more accurately than male faces. This finding was more robust for male children compared to female children. In contrast, adults exhibited a different pattern. Adult females were equally apt at recognizing male and female faces; however, adult males were biased to have superior recognition for male faces. These results demonstrate that the perceptual system of young children is likely fine-tuned in importantly different ways than adults. In other words, children’s’ perceptual systems are likely
honored to recognize attributes of primary caretakers while adults’ perceptual systems are calibrated to evaluate faces for different information (e.g., mate potential or potential competition). Interestingly, differences in children and adults’ processing advantages for faces of differing sexes was likely driven by developmental sex differences in males’ recognition patterns. Specifically, male children exhibited a sensitivity bias for female faces, while adult males demonstrated a recognition bias for male faces. Conversely, adult females did not evince a bias toward female or male faces during childhood or adulthood. These findings both negate and lend support to the current literature. First, these findings support previous work showing that males exhibit an own-sex bias in adulthood (Shaw & Skolnick, 1994, 1999; Wright & Sladden, 2003). However, in contrast to these findings, previous work has suggested that the own-sex bias is actually more robust in adult females than males (Armony & Sergerie, 2007; Lewin & Herlitz, 2002). As such, the current finding that adult males display an own-sex bias to a greater extent than adult females is novel and is largely inconsistent with prior research. Interpretations and possible explanations for why this may be will be explored in the general discussion section.

To date, this is the first study to demonstrate that males exhibit a shift in their processing advantage from female faces to male faces from childhood to emerging adulthood. These findings converge with hypotheses regarding the importance of developmental tasks in shaping face recognition abilities. However, it is notable that we did not have any clear predictions regarding sex biases in this experiment; thus, this finding was unexpected. Though, males’ processing advantage for female faces during early childhood is consistent with the theoretical framework, given that mothers disproportionately accompanied the children to testing sessions in the vast majority of this sample. This finding, in particular, leads to additional questions about whether and to what extent this processing advantage for own-sex faces in recognition abilities is shaped by pubertal development. Moreover, it is critical to evaluate whether age and gender biases in face recognition develop in tandem, particularly in adolescence when same-aged peer faces
become much more salient and relevant to the developmental tasks of adolescents. The developmental shift in recognition biases observed in Experiment 1 motivates further questions about whether the concomitant effects of pubertal development and novel developmental tasks related to adolescence has the potential to shift recognition patterns specifically during adolescence and as a function of pubertal development. Thus, an additional experiment was conducted to evaluate whether and to what extent the robust bias adults evince for same-aged peer faces emerges (and/or fluctuates) during adolescence as a function of pubertal development. It was predicted that if pubertal development is essential in shaping these biases toward peer-aged faces, then adolescents in later stages of pubertal development would evince more robust sex and age recognition biases compared to adolescents in earlier stages of pubertal development.
Chapter 3

Experiment 2

The second experiment was designed to systematically evaluate the full developmental trajectory of age- and sex-related biases from childhood up to young adulthood. Importantly, this was the first study of its kind to evaluate the development course of these biases by carefully dissociating age from pubertal effects. Relatedly, no studies to date have examined this bias in a population of adolescents, let alone the extent to which pubertal development or sex differences modulate this bias. To examine these processes, it was critical that prepubertal children and adults were incorporated as anchors for pubertal development (i.e., as representations of pre and post puberty). In this study, children (6-8), adolescents (11-14) of varying pubertal status, and adults (18-25) were all tested for an OAB.

SCTs emphasizing the influence of current experience would predict that participants would show superior recognition abilities for faces from their own age group, independent of pubertal state and age. In contrast, SCTs emphasizing the influence of cumulative lifetime exposure would predict that children would exhibit a bias for adult faces (because of their primacy in the early life of a child) and potentially same-age faces as well (due to extensive exposure to same age peers). Furthermore, adults and adolescents would not be expected to exhibit any biases, regardless of pubertal status, because they have been exposed to faces from each of these age groups in their lifetime. Under the novel theoretical model I aimed to test, I predicted that adults would exhibit the strongest recognition biases for other sexually mature adults (as was shown in Experiment 1), adolescents would exhibit biases only if they were in the late pubertal group and the biases would be toward peers that were also more sexually mature. This prediction was made with the idea that if pubertal development were key in shaping recognition biases toward peers, it would be most evident in the more advanced stages of puberty.
Finally, I expected that pre-pubertal children and adolescents in the earliest states of pubertal development would not exhibit any age-related biases toward peers. In fact, I predicted that they may still evince superior recognition abilities for adult faces (as was shown in the children from Experiment 1).

**Method**

**Participants**

Participants in this study were drawn from four developmental groups. Each group contained 20 participants. The first group included pre-pubertal 6-8 year olds (10 males; M = 7.35, SD = .59) (all Tanner stage 1). The second group included 11-14 year adolescents in the early stages of pubertal development (11 males; M = 11.95, SD = .94) (Tanner stages 1-2); the third group included age-matched 11-14 year old adolescents in the later stages of pubertal development (10 males; M = 12.35, SD = 1.09) (Tanner stages 3-5). The fourth group included sexually mature young adults (ages 18-25 years) (10 males; M = 19.90, SD = .99). It is critical to note that early and late pubertal adolescents were not significantly different from each other in terms of age, t(38) = 1.24, p = .22.

**Measures**

Pubertal status was assessed in terms of secondary sex characteristics (i.e. breast, phallic, testicular and pubic hair development) via the Tanner staging measure (Marshall & Tanner, 1968) as well as the Pubertal Development Scale (PDS, Petersen, Crockett, Richards, & Boxer, 1988) through parent and child report (depending upon the age of the participant). Parents of the
youngest participants (6-8 years) completed the Tanner staging form, judging the development of secondary sex characteristics in their own children, in order to confirm that they were indeed pre-pubertal. Participants ages 11 years and older (i.e., the adolescent group) were asked to complete the Tanner and PDS questionnaires themselves in addition to the parental report. Parents were also asked to report the last time they reported having the opportunity to observe their child naked, which ranged from the day of or prior to testing (most commonly reported for young children) to several years prior to testing (most commonly reported by parents of adolescent participants). Research has demonstrated that acquiring parent report prior to age 11 is comparable to physician report whereas self-report is more accurate from older children (11 and beyond) (Petersen, et al., 1988). Importantly, the PDS allowed us to measure how participants perceive their pubertal development in comparison to their peers (i.e. Do you think your development is any earlier or later than most other boys/girls your age?). The PDS also included questions about skin and voice changes, growth spurt, body hair, breast development, and menstruation; all important features of pubertal development that reflect distinct developmental processes (i.e., adrenal and gonadal development). In sum, we acquired multiple measures of pubertal development across multiple observers, which enhanced the validity and reliability of the combined measures that were used to determine the final stage of grouping adolescents into the early or late pubertal groups.

Participants in the adolescent group were sorted into the early or late pubertal development groups after testing and based on a composite score of the Tanner and PDS self- and parent-report measures. All four measures were considered in the assessment of stage. This was a multi-stage process. First, the self-report and parent-report PDS scores were both converted to Tanner staging scores using an algorithm developed by Shirtcliff, Dahl, & Pollak (2009) (an improved version of Petersen, Crockett, Crockett, Richards, & Boxer (1988) composite code). The algorithm allows for the examination of items from the PDS that reflect the adrenal and
gonadal development separately. For males, a gonadarche score was compiled from PDS items that asked about facial hair growth, voice deepening, and growth spurt as well as items from the Tanner reflecting penis and testis maturation. For females, a gonadarche score was compiled based on PDS items probing changes in breast development as well as the onset of menses. Adrenarche scores for both boys and girls were compiled based on pubic hair growth, body hair growth, and skin changes. These scores were compiled via averaging for the respective gonadal and adrenal developmental processes, and then the overall composite score.

Second, for each adolescent, all sets of pubertal development scores (Tanner stage – self report, Tanner stage – parent report, PDS converted Tanner – self report, PDS converted Tanner – parent report) were used to group them into the early or late developing group. Only adolescents whose scores (both parent and adolescent) consistently identified them as in the early stages of pubertal development (1-2) were placed in the early group and those whose scores consistently identified them as in the later stages of pubertal development (3-5) across all 4 measures were placed in the late group. Any participants who had discrepant scores across the four measures (e.g., reported being a 2 on the Tanner and a 4 on the PDS) were not included in the present sample. In this way, there is strong validity and reliability across the measures and observers reporting on pubertal development. In addition, to ensure that the children (6-8) were not undergoing early gonadal development, the final sample of children only included those who were deemed to be a Tanner 1 by their parents (as in Experiment 1).

Sample Selection

After inclusion criteria were met and pubertal sorting was completed, 20 participants from each group were selected for the final analyses. In the adolescent group, 6 participants were excluded on the basis of lower than chance performance. First, 20 participants in the earlier stages
of pubertal development were collected. Next, I collected data until we were able to obtain 20 age-matched adolescents in the later stages of pubertal development, which required testing of approximately 40 additional adolescents. Finally, I randomly selected 20 gender-matched children and 20 gender-matched adults from the original sample described in Experiment 1.

**Stimuli**

Stimuli were all collected and edited as described in the General Methodology section. Recall, images included male and female faces (5 male and 5 female targets) for each block. It is important to note that for the adolescent faces, 25 adults rated the sexual maturity of the faces on a 1-5 scale. Adults were given “anchor” examples of a young prepubescent face and a sexually mature face to help guide their ratings during the task. Face stimuli that were consistently ranked less than 3 (+/- 1 SD) on the scale were used to represent the early pubertal development group and faces that were ranked greater than 3 (+/- 1 SD) were used to represent individuals from the later pubertal group. In order to ensure that the distribution of rankings was non-overlapping, we only selected faces that were 1.5 or more standard deviations above or below a ranking of 3. Specifically, faces designated as early pubertal had to be ranked at least 1.5 standard deviations below 3 while faces designated as late pubertal had to be ranked at least 1.5 standard deviations above 3.

**Experimental Paradigm**

The experiment consisted of a 4 (developmental groups: prepubertal children, early pubertal adolescents, later pubertal adolescents, adults) x4 (conditions: prepubertal child face, early pubertal adolescent faces, later pubertal adolescent faces, and adult faces) design in which
all participants recognized faces of individuals from all development groups. The task design is identical to that described in the General Methodology section.

Results

Two separate repeated measures ANOVAs were conducted on A’ sensitivity (as a measure of accuracy) and mean correct RT. To evaluate the extent to which there were sex differences in accuracy and speed with which children, adolescents in the earlier and later stages of puberty, and adults processed different age and sex faces, an omnibus repeated-measures ANOVA was conducted with the within-subject factors of age of stimuli (4: child, early puberty, late puberty, and adult) and sex of stimuli (2: male, female) and the between-subjects factors of participant group (4: child, early puberty, later puberty, adult) and participant sex (2: male, female). Higher-order interactions were investigated by holding between-subjects factors constant in order to investigate lower-level interactions. Finally, simple effects of lower-order interactions were investigated with t-tests to evaluate the magnitude of condition and sex differences. There were no violations of sphericity and the groups were comparable in variance across the measures.

A’ Sensitivity

The comprehensive set of results from the omnibus ANOVA is presented in Table 2. As in Experiment 1, there was a main effect of age of stimuli, F(3, 70) = 8.36, p = .000, η²p = .10 (refer to Table 2). However, Bonferroni corrected post-hoc tests revealed that the only reliable differences were between recognition abilities for late adolescent faces (M = .58, SE = .03) and adult faces (M = .72, SE = .02) (p = .06). There were no significant differences among participant
sensitivity to recognizing early adolescent faces (M = .69, SE = .02) or child faces (M = .58, SE = .02) as compared to the other stimuli age groups (see Figure 7).

Table 2-1: Experiment 2 Repeated Measures ANOVA A’ Sensitivity Results (4x2x4x2: Participant Developmental Group, Participant Sex, Age of Stimuli, Sex of Stimuli).

<table>
<thead>
<tr>
<th>Main Effects</th>
<th>dF</th>
<th>F</th>
<th>( p )</th>
<th>( \eta^2_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of Stimuli</td>
<td>3, 70</td>
<td>8.36</td>
<td>(&lt;.001)</td>
<td>0.104</td>
</tr>
<tr>
<td>Sex of Stimuli</td>
<td>3, 70</td>
<td>1.97</td>
<td>0.164</td>
<td>0.027</td>
</tr>
<tr>
<td>Participant Sex</td>
<td>3, 70</td>
<td>.297</td>
<td>0.587</td>
<td>0.004</td>
</tr>
<tr>
<td>Participant Group</td>
<td>3, 70</td>
<td>1.60</td>
<td>0.197</td>
<td>0.063</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interactions</th>
<th>dF</th>
<th>F</th>
<th>( p )</th>
<th>( \eta^2_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant Group x Participant Sex x Sex of Stim</td>
<td>3, 70</td>
<td>3.53</td>
<td>0.019</td>
<td>0.128</td>
</tr>
<tr>
<td>Participant Group x Sex of Stim</td>
<td>3, 70</td>
<td>3.82</td>
<td>0.013</td>
<td>0.137</td>
</tr>
<tr>
<td>Participant Sex x Sex of Stim</td>
<td>3, 70</td>
<td>6.05</td>
<td>0.016</td>
<td>0.078</td>
</tr>
<tr>
<td>Participant Group x Age of Stim</td>
<td>3, 70</td>
<td>2.03</td>
<td>0.038</td>
<td>0.078</td>
</tr>
<tr>
<td>Participant Group x Age of Stim x Sex of Stim</td>
<td>3, 70</td>
<td>0.497</td>
<td>0.876</td>
<td>0.020</td>
</tr>
<tr>
<td>Participant Sex x Age of Stim</td>
<td>3, 70</td>
<td>1.76</td>
<td>0.156</td>
<td>0.024</td>
</tr>
<tr>
<td>Participant Group x Participant Sex x Age of Stim</td>
<td>3, 70</td>
<td>0.500</td>
<td>0.874</td>
<td>0.020</td>
</tr>
<tr>
<td>Participant Sex x Age of Stim</td>
<td>3, 70</td>
<td>0.499</td>
<td>0.863</td>
<td>0.007</td>
</tr>
<tr>
<td>Part Group x Part Sex x Age of Stim x Sex of Stim</td>
<td>3, 70</td>
<td>1.37</td>
<td>0.205</td>
<td>0.054</td>
</tr>
</tbody>
</table>

*Notes.* Significant at \( p<0.05 \) level.
There was also a significant interaction between the sex of the stimuli and participant group, $F(3, 70) = 3.82, p = .01, \eta^2 p = .14$. In addition, there was a significant participant sex x sex of the stimuli interaction, $F(3, 70) = 6.05, p = .02, \eta^2 p = .08$. However, these interactions were qualified by a higher order interaction of sex of the stimuli x participant sex x participant group, $F(3, 70) = 3.53, p = .02, \eta^2 p = .13$. To examine this highest order 3-way interaction, we evaluated lower-order interactions between sex of the stimuli x sex of participant within each age group separately. Figure 8 shows that among children, there was a significant sex of participant x sex of stimuli interaction, $F(1,18) = 3.52, p = .04, \eta^2 p = .12$. Male children were more sensitive to recognizing female faces ($M = .71, SE = .04$) compared to male faces ($M = .61, SE = .04$), $t(9) = 3.20, p = .01$ (Figure 8a). These findings are consistent with results from Experiment 1. Similarly, female children tended to have superior sensitivity for recognizing female ($M = .72, SE = .04$) compared to male ($M = .63, SE = .04$) faces, $t(9) = 2.13, p = .06$. 

Notes. Post-hoc bonferroni tests trending toward significance at $p<0.10$ level.

Figure 7-1: Overall sensitivity for developmental group of stimuli from experiment 2.
In the early puberty group, there were no main effects or interactions. In other words, neither males (t(10) = 1.19, p = .26) nor females (t(8) = 0.42, p = .69) displayed enhanced sensitivity for recognizing either male or female faces (Figure 8c). Interestingly, in the late puberty group, there was a sex x sex interaction, F(1,18) = 8.76, p = .01, \eta^2_p = .33. Adolescent males in the later stages of pubertal development demonstrated significantly better sensitivity for recognizing male (M = .71, SE = .03) compared to female (M = .60, SE = .05) faces, t(9) = 1.99, p = .07 (Figure 8d). Conversely, female adolescents in later stages of pubertal development showed significantly higher sensitivity for recognizing female (M = .66, SE = .03) compared to male (M = .57, SE = .04) faces, t(9) = 2.23, p = .05. Finally, among adults, there was a sex of participant x sex of stimuli interaction as in Experiment 1, F(1,18) = 3.51, p = .03, \eta^2_p = .21. Similar to Experiment 1, adult males exhibited heightened sensitivity in their recognition for male (M = .74, SE = .03) compared to female faces (M = .64, SE = .06), t(9) = 2.67, p = .02 (Figure 8b). Females did not evince biases toward male (M = .73, SE = .03) or female (M = .75, SE = .05) faces, which is also convergent with findings from Experiment 1, t(9) = .513, p = .62.
There was also a significant 3-way participant group x age of stimuli x sex of stimuli interaction, $F(3, 70) = 2.03$, $p = .04$, $\eta^2_p = .08$. To examine this higher order interaction, we evaluated lower-order interactions between sex of the stimuli x age of stimuli within each age group separately. In children, there was a significant age of stimuli x sex of stimuli interaction, $F(1,18) = 3.29$, $p = .03$, $\eta^2_p = .15$. In all other groups there were no significant interactions in their ability to discriminate male and female faces within the 4 different stimuli age groups. To further investigate the interaction in the children, I conducted paired t-tests comparing A’ sensitivity to recognize male and female faces within each stimulus age group. This revealed that

Notes. Pairwise t-tests significant at $p<0.05$ level.

*p < 0.07

**p < 0.05

Figure 8-1: Sensitivity to recognizing male and female faces graphed as a function of group from experiment 2.
children were more sensitive to recognizing female child faces (M = .74, SE = .03) compared to male child faces (M = .59, SE = .06), t(19) = 2.75, p = .01. Children were also more sensitive to recognizing female adolescent late puberty (M = .69, SE = .05) compared to male adolescent late puberty (M = .50, SE = .05) faces, t(19) = 2.99, p = .01.

Given the a priori hypotheses that sensitivity to sex of face and age of face would vary as a function of development, we sought to further investigate group differences in sensitivity to these face characteristics. In order to compare groups on their sensitivity to sex and age of stimuli, difference scores of the male and female faces within each stimuli age group were calculated for each individual. Specifically, differences scores were calculated for each participant using the following formula: mean sensitivity for female faces – mean sensitivity for male faces from each stimulus age group. For example, for sensitivity for child faces, mean sensitivity for male faces was subtracted from mean sensitivity for female faces. Therefore, if a participant was more capable at recognizing female faces, their difference score would be positive. These difference scores were submitted to separate one-way ANOVAs for each stimulus age group with the between-subject factor of participant age group. There was a main effect of participant age group, for child face stimuli (F(3) = 4.04, p = .01) and late pubertal face stimuli, (F(3) = 3.81, p = .01). Post hoc Bonferroni tests uncovered that children had a female bias when recognizing child faces (M = .15, SD = .24), whereas adults had a male bias when recognizing child faces (M = -.15, SD = .37) (p = .01) (Figure 9; plotted in mean A’ sensitivity scores). In addition, when recognizing adolescent late pubertal faces, children also exhibited a female bias (M = .19, SD = .28), whereas the later pubertal adolescents had a bias to toward male faces when recognizing the adolescent late pubertal faces (M = -.08, SD = .30) (p = .01). There were no other significant or otherwise notable results from this post-hoc comparison.
Reaction Time

There was a main effect of group, \( F(1, 70) = 3.50, p = .02, \eta^2p = .13 \), whereby reaction time decreased across the developmental groups (Figure 10). Post-hoc Bonferroni comparisons revealed that children’s reaction time (\( M = 1.56, SE = .08 \)) differed significantly from adolescents in the later stages of puberty (\( M = 1.23, SE = .08 \)) and adults (\( M = 1.22, SE = .08 \)) (all \( p < .05 \)). Conversely, reaction times for the adolescents in the earlier stages of puberty (\( M = 1.39, SE = \))

Notes. Post-hoc bonferroni tests trending toward significance at \( p<0.05 \) level.

Figure 9-1: Sensitivity to male and female faces across stimuli age graphed as a function of group from experiment 2.
.09) did not differ significantly from any of the other groups. No other main effects or interactions were uncovered in any other factors examined.

![Graph showing overall speed by participant group from experiment 2.](image)

*Notes. Post-hoc bonferroni tests trending toward significance at p<0.05 level.*

Figure 10-1: Overall speed by participant group from experiment 2.

**Low-Level Perceptual Characteristics**

In order to consider whether there were unanticipated low-level differences in the perceptual characteristics of the groups of face stimuli, we used an in-house Matlab script with the function normxcorr2 to assess the degree of similarity between the set of images. This enabled us to compute a pixel-wise correlation of the luminance between all pairs of faces within each set of faces (e.g., child faces). These correlations were then submitted to a one-way ANOVA to evaluate whether the groups of stimuli were different in perceptual similarity. To be clear, a high correlation value indicated that the faces within the group were more perceptually similar, making
the faces harder to discriminate based on purely visual characteristics. Conversely, a lower correlation value indicated that the faces within the group were less perceptually similar, making it easier to discriminate among the faces based on low-level visual differences.

First, we compared the perceptual similarity of the entire image within each group, which included the face and the background (i.e., black background and neck region). This analysis revealed that the images did differ, $F(3, 1736) = 63.81, p = .000$. Post-hoc Bonferroni analyses indicated that the adult faces ($M = 0.731$) were the most perceptually similar, compared to all other groups, making them potentially more difficulty to discriminate based purely on low-level visual information ($p = .02$). Next, we computed the perceptual similarity of the face portion of the image in the absence of the background. This analysis also indicated that the images differed, $F(3, 1736) = 7.00, p = .000$ (Figure 11 and 11.1). Post-hoc bonferroni comparisons revealed that the late pubertal faces ($M = .74$) were significantly more perceptually similar (i.e., more difficult to discriminate) compared to the child ($M = .680; p = .04$) and early pubertal faces ($M = .656; p = .03$). Importantly, this analysis did not indicate that the adult faces ($M = .721; p = .70$) were significantly different from the late pubertal faces, which cannot help to explain the overarching pattern of results indicating that most participants performed better on adult faces.
Notes. Post-hoc bonferroni tests trending toward significance at p<0.05 level.

Figure 11-1: Low-level visual characteristics of face stimuli & background. Adult faces were the most perceptually homogenous.

Notes. Post-hoc bonferroni tests trending toward significance at p<0.05 level.

Figure 11-2: Low-level visual characteristics of face stimuli only. Late puberty faces were the most perceptually homogenous.
Experiment 2 Discussion

The goal of Experiment 2 was to evaluate the extent to which pubertal development, independent of age, shapes face recognition biases. This was the first study to dissociate the relative contributions of age and puberty in order to evaluate the extent to which pubertal development impacted the emergence of face recognition biases. Moreover, this was the first study to incorporate sex of the participant and of the observer as contributing factors. A secondary aim of this experiment was to examine the full trajectory of these biases, from pre-pubescent children to sexually mature adults, in the same statistical model.

Findings from Experiment 2 revealed that all participants were best at recognizing adult faces. Though, there were only trending differences in recognition ability for adult faces and late puberty faces. Interestingly, recognition for early pubertal faces was comparable to adult faces across participants. This finding should be considered with caution given that the early pubertal face stimuli were the most perceptually dissimilar, making it the easiest block of faces to recognize. In other words, low-level perceptual characteristics could be contributing to heightened recognition abilities for early pubertal faces. However, in spite of the low-level perceptual homogeneity of the adult faces, participants still displayed an accuracy advantage for recognizing adult faces. These findings rule out the possibility that participants were simply using low-level visual characteristics to more accurately identify the adult faces.

Importantly, results from the present experiment replicated those of Experiment 1 in that we were able to demonstrate that prepubertal male children tended to show a processing advantage for female faces. It is also notable that this same recognition pattern was significant in prepubertal female children. This finding supported the predictions of the novel theoretical model being tested here such that children were predicted to have superior recognition for female faces,
given that this skill is thought to be necessary and indicative of mastery of developmental tasks in childhood (i.e., formation and maintenance of attachment relationships with primary caretaker).

Interestingly, adolescents in the earlier stages of pubertal development did not demonstrate any clear recognition pattern toward male and female faces (nor toward their own peer group). These results coincided with my predictions regarding sex differences in sensitivity to male and female faces as it relates to pubertal development. That is, if sex hormones are related to changes in recognition patterns (including sexual dimorphism in these patterns), it is unsurprising that adolescents in the earlier stages of pubertal development do not evince recognition biases toward particular sexes. In other words, this lack of clear organization in the behavior may be an indication that there we observed a puberty-related disruption in the organizational pattern of face recognition behaviors. This interpretation is bolstered by the fact that same-age participants in the later stages of pubertal development evinced a stable and unique recognition pattern, such that males and females showed an emerging pattern of an own-sex bias. This new behavioral manifestation in the late pubertal adolescents may represent a critical shift in functional and structural organization of the brain incited by pubertal hormones. This emerging pattern found the late pubertal males became significant in the adults, such that adult males had enhanced recognition ability for male faces. Consistent with findings from the first experiment, female adults did not evince an own-sex bias.

Lastly, this study also provided novel findings regarding processing advantages found within development groups for own-age and other-age faces of different sexes. Specifically, children exhibited dramatic differences in their sex biases for different age groups while all other age groups seem to exhibit similar patterns. Children demonstrated stronger biases toward female child faces as well as late pubertal female faces. The only set of faces that children did not have a female bias for was the early pubertal group. It could be the case that the children in our sample had older siblings (or babysitters) that were primarily female (and not male) in the later stages of
puberty and/or older siblings in the earlier stages of pubertal development that were male. It is
difficult to ascertain the extent to which experience contributed to the biases found in the results
from this paradigm. Despite these alternative hypotheses, these findings provide novel insight
into differences in processing advantages for recognizing different age and sex faces across
development.
Chapter 4

General Discussion

The present study evaluated the relative contributions of pubertal development and age in the development and emergence and developmental course of biases in face recognition behavior from childhood through early adulthood. Overwhelmingly, the results suggest that, age-related biases are directed toward young adult faces in both children and adults. In Experiments 1 and 2, both children and adults were more accurate at recognizing young adult faces compared to child faces. In other words, adults, but not children exhibit an OAB. Children exhibit an age-bias toward adults. Also, children in this sample were more accurate at recognizing female faces, whereas young adults showed a different pattern. Young adult males exhibited an own-gender bias and were better at recognizing male faces, while young adult females were equally apt at recognition male and female faces. Experiment 2 was able to build upon these findings by establishing that contrary to our predictions, adolescents do not show the emergence of an OAB; instead, they too tend to show more accurate recognition for young adult faces. That is, recognition biases did not become shaped around peer faces for adolescents during pubertal development. However, pubertal development influences the formation of adult-like patterns of gender biases in face recognition behavior. As such, the current study provides support for the notion that the developmental trajectories of age- and gender-related biases are subject to different influences, with pubertal development primarily influencing gender-related biases.

It may be the case that biases toward peer faces (especially in adolescence) are apparent in more affective and social components of face processing. For example, it is plausible that the ability to detect particular expressions that are indicative of critical shifts in development tasks would be a better measurement of peer biases. More specifically, a task that probes individuals’
ability to detect a basic expression (e.g., anger) versus a more complex expression (e.g., contempt) may be a more sensitive measure of whether the preeminent developmental tasks are shaping face-processing abilities in fundamentally new ways.

This study represents a novel contribution to the literature given that this was the first study to our knowledge to evaluate these biases across development in addition to evaluating the extent to which pubertal development, irrespective of age, impacted recognition biases. Moreover, results from this study are inconsistent with some of the current perspectives and findings in the literature. More specifically, previous work has been largely mixed with respect to whether children evince an own-age bias (OAB). That is, some research has shown that children evince an OAB (Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Goldstein & Chance, 1964; Hills, 2012; Lindholm, 2005) while others have shown that children demonstrate biases toward adult faces (Cassia, Kuefner et al., 2009; Cassia, Piscacane, & Gava, 2012; Proietti, Piscacane, & Cassia, 2012). Some studies have even shown that children do not show age-related biases at all (Mondloch, Maurer, & Ahola, 2006). Our findings are consistent with work demonstrating that children evince a processing advantage for adult faces (3 year olds; Cassia, Luo, Piscacane, Li, & Lee, 2014), which supports predictions made by Scherf and Scott’s novel theoretical model. That is, prepubertal children would be expected to evince biases toward adult faces given that this age group maintains primacy in the earliest stages of development in terms of establishing and maintaining attachment bonds. Findings from adults are largely consistent with the current literature such that adults have previously been found to demonstrate strong biases toward same-age peers (Anastasi & Rhodes, 2005, 2006; Ebner & Johnson, 2009; Hills & Lewis, 2011; Wright & Stroud, 2002). These findings are also consistent with Scherf and Scott’s framework, which predicted that adults would display the strongest processing advantage for other sexually mature adult faces.
Sex as a Critical Factor in Face Recognition Bias Emergence

The current study established the importance of evaluating the dynamic interplay between participant sex, developmental factors (e.g., puberty), as well as the sex of the face individuals are recognizing. Findings regarding the interaction between sex of the stimuli and sex of observer were largely unexpected, but support Scherf and Scott’s theoretical framework. It is clear from the present findings that future studies must systematically measure these factors with a priori predictions, especially in considering the emergence of particular sex-related biases. That is, the present study revealed that there are distinct recognition patterns associated with different points in development, and possibly different emerging developmental tasks. Consistent with predictions from Scherf and Scott, children (especially males) had enhanced recognition abilities for female faces. This finding is largely consistent with the notion that it is functionally advantageous for children to have superior recognition for faces that are most representative of their primary caretakers (e.g., usually mothers; but see Quinn, et al., 2002 for evidence supporting superior recognition for fathers who are primary caretakers). It would not suffice to say that these findings are consistent with the either the lifetime experience or most recent exposure hypothesis, given that the children in this study were likely exposed to many peers. In other words, these findings may not necessarily be explained by the notion that individuals’ perceptual systems are fine-tuned to recognize faces that are overrepresented in their environment. Results from this study should garner some appreciation for which faces in one’s environment may become privileged in perceptual systems as a function of motivational factors (e.g., developmental tasks). The findings from the children in this study serve as a prime example of this given that they show strong recognition biases toward adult faces, despite being school-aged children. That is, it is likely that children in our sample had substantial exposure to other children their age, in addition to primary caretakers, which may present competition in terms of demands placed on perceptually
tuning. In this way, this finding builds upon previous findings that infants evince strong biases toward female faces by demonstrating that this bias may extend into later years of childhood development and is largely centered on characteristics aligning with those of primary caretakers (Quinn et al., 2010; Quinn et al., 2002; Ramsey-Rennels & Langlois, 2006; Rennels & Simmons, 2008). Moreover, this finding may inherently challenge notions that mere exposure is sufficient to induce biases in face processing (e.g., for same age peer faces).

The Emergence of an Own-Sex Bias in Males

For adolescents in the later stages of pubertal development, there is a new emergent pattern that is distinct from prepubertal children and sexually mature adults. Particularly, adolescents in the later stages of puberty show an emerging bias toward own-sex faces, such that females show enhanced recognition for female faces and males show enhanced recognition for males. This finding is consistent with our predictions based on findings from Experiment 1 in that we predicted that adolescents in the later stages would demonstrate a more robust pattern of sex biases compared to adolescents in the earlier stages of development. Given that the adolescent participants in our sample were carefully matched on age, I conclude that the influence of pubertal development contributed to the emergence of this distinct recognition pattern.

It is also important to note that this pattern was not necessarily an “adult-like” pattern, given that adults displayed a slightly different pattern of face recognition. Specifically, the emerging pattern in the late pubertal adolescent males toward other male faces was more robust in adult males. Also, consistent with Experiment 1, female adults did not demonstrate superior recognition for female faces. This finding is particularly interesting, given that we were able to replicate this in a random subset of our adult sample and because it is inconsistent with findings from the current literature regarding own-sex biases. Previous literature reports that female adults
demonstrate strong own-sex biases as compared to male adults (Godard & Fiori, 2010; Hall, Hutton, & Morgan, 2010; Hampson, et al., 2006; Lewin & Herlitz, 2002). In contrast, this study demonstrated that not only did adult women not surpass adult men in face recognition performance, but they did not evince a stronger own-sex bias. Though it is difficult to interpret a null result, the current finding does not support the notion of the existence of the own-sex bias in females.

Conversely, adult males in our sample displayed stronger recognition biases toward male faces, indicating that they do have an own-sex bias. This is not consistent with prior literature suggesting that adult males do not have a reliable own-sex bias (Lovén, Herlitz, & Rehnman, 2011). It may be that making attributions about same-sex faces is critical for males in efforts to evaluate competition for mate selection. Previous work has shown that facial traits are used to make rapid evaluations of characteristics such as trustworthiness and dominance (Stirrat & Perrett, 2010; Todorov, Pakrashi, & Oosterhof, 2009; Windhager, Schaefer, & Fink, 2011). For males in particular, making evaluations of who will be the most relevant and irrelevant competitors within a social hierarchy may be a critical skill that emerges during adolescence and continues to develop into adulthood. Moreover, being able to make these evaluations has been shown to have palpable functional utility; for example, males whose faces were rated as more aggressive have been shown to actually be more aggressive in the real world, which demonstrates that it is critical for individuals to be able to make such attributions (Carré, McCormick, & Mondloch, 2009). As such, this developmental finding adds to the literature by demonstrating that males experience a critical shift in their sex biases, going from superior recognition for females to superior recognition for males later, specifically after the onset of pubertal development.
Reorganization of Behavior as a Function of Puberty

This study was also able to show a puberty-related disruption in recognition abilities for different sex faces. That is, in the adolescents in the earlier stages of pubertal development, there was no clear pattern of organization in terms of their recognition abilities for male and female faces. This was in stark contrast to the adolescents in later stages of pubertal development, who showed a clear emergent pattern of sex biases. This finding lends support for prior work demonstrating that adolescent girls show a dip in face recognition ability performance around age 12 that rises and plateaus around age 16 (Carey, Diamond, & Woods, 1980). Our finding supports this seminal work given that our sample was an average age of 12, which suggests that perhaps the surge of gonadal hormones occurring in the beginning of puberty provoked a reorganization of behavior. In so doing, this reorganization may have temporarily destabilized, and even disrupted, performance. Other models have also suggested that the infusion of gonadal hormones during pubertal development leads to a disruption in existing recognition behaviors in order to reorganize and bring on novel skills and behaviors (Scherf, Behrmann & Dahl, 2012; Scherf, Smyth, & Delgado, 2013). Indeed, adolescents in the earlier stages of pubertal development must accommodate a confluence of the biological, affective, and cognitive changes occurring in addition to the onset of new developmental tasks (e.g., forging autonomy from parents, forming strong peer relationships). This re-organization of biological and social-affective/environmental components likely incites a disruption in behaviors that already exist in order to bring on novel behaviors for the purposes of mastering developmental tasks.
Limitations

Though the current study provides a substantial contribution to the current literature in a variety of ways, there are a few caveats to note. First, the differences in the low-level perceptual characteristics of the stimuli should be acknowledged. These differences certainly do not diminish the value of the findings from this study, but they are notable in that they may have influenced some of the results regarding the early pubertal adolescent faces in particular, given that they were the easiest. However, it is noteworthy that there were not any significant findings regarding this set of faces. In fact, the overarching finding from this study is that some individuals (namely children and adults) have a bias toward adult faces (the most difficult stimuli category, based on one of the stimuli analyses).

Another limitation with the design of our study is that it was a cross-sectional design, making it difficult to make any causal interpretations about the developmental data. Though it is not as feasible to employ a longitudinal design compared to a cross-sectional design, it may be advantageous for future research to use an accelerated longitudinal design in order to establish stronger claims about the intraindividual change across development, especially with respect to pubertal development. In addition, using such a design would allow for more fine-grained analysis of potential individual differences in the emergence of these recognition biases.

Lastly, it is notable that the present study does not allow us to make any claims about the impact of experience in shaping these biases. It is well-established that experience plays a critical role in the shaping biases in recognition ability (Kuefner, Cassia, Picozzi, & Bricolo, 2008; Cassia, Picozzi, Kuefner, & Casati, 2009). As such, understanding the extent to which there are unique experiences that may account for individual differences or outliers is extremely valuable in understanding the dynamic nature of how face recognition biases are shaped. Moreover, there is precedent in the literature for surveying the quality and quantity of individuals’ experience with
particular groups in order to better understand the nature of biases and what factors modulate them.

**Future Directions**

Given the interesting findings from the present study, there is substantial room for future work to build upon the present findings. For example, given that the present study did not find any peer-related biases aside from the adult participants, it may be useful for future studies to incorporate a set of older adolescents. It may be that the age range of the participants included in the present study were too young to see the shift toward biases for peer faces. Moreover, including older adolescents may help to better understand the temporal sequence of when age and sex biases emerge and fluctuate. That is, it may be the case that sex-biases toward same-sex faces precedes own-age biases during adolescence and emerging adulthood.

Relatedly, future work will need to make efforts to directly link developmental tasks with recognition biases. More specifically, administering measures that assay individuals’ progress toward mastering particular developmental tasks and linking them to face recognition abilities will be extremely informative given the present findings. For example, tracking an individuals’ progress toward the developmental task of forming intimate peer relationships during adolescence may be strongly linked to enhanced recognition for peer faces. Systematically evaluating the relationship between puberty, developmental tasks, and face recognition abilities will be vital for future work to address.

Since we were not able to uncover any biases toward peer-aged faces in the adolescents, it may be that other types of face processing behaviors are more amenable to observing the reported reorientation toward peers during adolescence. As previously mentioned, the use of tasks
that probe the more affective components of face processing may be more suitable for investigating biases toward peer faces. For example, a task that measures one’s ability to detect basic (e.g., happy) versus complex (e.g., flirtatious) expressions may be a more sensitive measure of reorientation toward peers. In a task like this, it may be expected that adolescents in the later stages of pubertal development evince more sensitivity to complex expressions, while children and those in the earlier stages of pubertal development evince less sensitivity to complex expressions.

**Conclusions**

The present study represents a novel contribution to the literature in that it was able to disentangle effects of age and pubertal development on face recognition biases. Secondly, this study was the first to examine the unique intersection of two biases (i.e., age biases and sex biases) across development. Findings here demonstrated that in childhood and emerging adulthood, perceptual systems are tuned to having superior recognition for adult faces. This study was able to illuminate important distinctions in the emergence of sex differences in enhanced recognition abilities for male and female faces. Prior to puberty, children’s perceptual systems seem to largely be tuned to characteristics exemplifying their primary care takers (i.e., female and adult faces). In addition, at the onset of pubertal development there was a disruption in processing different sex faces, while later in pubertal development a new pattern of recognition emerged that differed across males and females. This study represents a novel contribution to knowledge about the emergence and fluctuations in age- and sex-related biases in face recognition abilities across development.
Appendix

Figure Legends

**Figure 1-1.** Examples of grey-scaled images of each developmental age group used as stimuli for the task.

**Figure 2-1.** A schematic diagram of the paradigm with examples from the child block. Participants view 10 neutral targets during encoding followed by a delay period with a short movie trailer. Next, participants were tested on happy targets and distractors in the test phase. Note that children had 3000ms to encode the stimuli, while adults and adolescents had 2000 ms. Likewise, the children had 5000ms to respond during testing, while adults and adolescents had 3000ms.

**Figure 3-1.** Sensitivity to child and adult faces collapsed across child and adult groups from experiment 1. Higher levels of a’ sensitivity indicate better recognition for particular faces. Overall, participants exhibit significantly higher sensitivity to recognizing adult faces ($p = .000$).

**Figure 4-1.** Sensitivity the child and adult faces graphed as a function of group from experiment 1. Adults and children perform comparably on child faces ($p = .32$). Both groups exhibit robust biases toward adult faces, with adults performing significantly better on adult faces compared to children ($p = .02$).

**Figure 5-1.** Group differences for male and female faces graphed as a function of group and sex of participant from experiment 1. Male children exhibited heightened sensitivity to
recognizing female faces compared to male faces ($p = .007$) (a), while female children did not evince heightened sensitivity for either male or female faces ($p = .10$). Conversely, adult males showed higher sensitivity to recognizing male faces ($p = .002$) (b), whereas females did not show modulations in sensitivity to male or female faces ($p = .64$).

**Figure 6-1.** Mean correct reaction time for male and female faces collapsed across group from experiment 1. All participants perform significantly faster when recognizing female faces compared to male faces ($p = .04$).

**Figure 7-1.** Sensitivity for recognizing faces from each developmental group collapsed across participant group from experiment 2. Only a marginal difference emerged where participants had higher sensitivity to adult faces compared to late puberty faces ($p = .06$). There were no other notable or significant differences between sensitivity for all other stimuli groups.

**Figure 8-1.** Sensitivity to recognizing male and female faces graphed as a function of group from experiment 2. In (a), prepubertal both male and female (trending) children demonstrated a bias toward female faces compared to male faces (males: $p = .01$; females: $p = .06$). In (c), early adolescent males and females did not show any clear pattern of biases toward male or female faces (males: $p = .26$; females: $p = .69$). In (d), female adolescents in the later stages of puberty show biases toward female faces ($p = .05$). Male adolescents in the later stages of puberty also show a trending result toward higher sensitivity toward male faces ($p = .07$). Lastly, in (b), adult males show significantly more sensitivity toward recognizing male faces ($p = .02$), while adult females do not show any sex-related biases in the form of sensitivity ($p = .62$).
Figure 9-1. Sensitivity to male and female faces across the different developmental stimuli groups graphed as a function of group from experience 2. Prepubertal children perform best on female adult faces. Prepubertal children evince higher sensitivity than adult to recognizing adults on child female faces ($p = .01$). The adolescents in the later stages of puberty show enhanced sensitivity toward recognizing late puberty male faces compared to children, who were better at recognizing late puberty female faces ($p = .03$). No other group comparisons were significant in the post-hoc analyses.

Figure 10-1. Overall mean correct reaction time graphed as a function of participant group from experiment 2. Participants become faster as a function of developmental group with children being the slowest and adults being the fastest of the groups. Adults were significantly faster compared to children ($p = .02$). Late pubertal adolescents were also significantly faster than children ($p = .02$).

Figure 11-1. Stimuli comparison across blocks based on low-level visual characteristics of the face stimuli and the background (i.e., entire image). Mean correlation values differ significantly between the adult face block and all other blocks such that the adult face block was the most perceptually homogenous ($p = .000$), which reflects that the adult block was the most difficult.

Figure 11-2. Stimuli comparison across blocks based on the low-level visual characteristics of the face stimuli only (without background or neck portions of the image). Mean correlation values indicate that late puberty faces were the most difficult and were statistically more perceptually homogenous compared to child faces, early puberty faces, and late puberty
faces ($p = .000$). Notably, the late puberty faces and the adult face did not differ significantly in their low-level visual properties.
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