Of kith and kin:

Perceptual enrichment, expectancy and reciprocal processing in face perception

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Abstract

Race powerfully affects perceivers' responses to faces, promoting biases in attention, classification, and memory. To account for these diverse effects, we propose a model that integrates social cognitive work with two prominent accounts of visual processing (perceptual learning and predictive coding). Our argument is that differential experience with a racial ingroup promotes both (a) *perceptual enrichment,* including richer, more well-integrated visual representations of ingroup relative to outgroup faces, and (b) *expectancies* that ingroup faces are more normative, which influence subsequent visual processing. By allowing for "top-down" expectancy-based processes, this model accounts for both experience- and non-experience-based influences, including motivation, context and task instructions. Fundamentally, we suggest that the psychological impact of race is largely attributable to the fact that human beings live and interact primarily with members of racial ingroups. Although race has little inherent meaning, we treat it as an important dimension because it structures our social environment, which in turn structures mental representation.

Key words: face processing; race; perceptual expertise; attention; categorization

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1. Overview and goals

The goal of this paper is to present a new model of face perception. In doing so, we attempt to account for diverse psychological effects typically associated with race (e.g., enhanced attention to, and poorer recognition of, outgroup faces), and to do so mechanistically, offering a relatively detailed account of visual processes subserving these effects. Using this mechanistic/process framework, the model also strives to integrate existing explanatory accounts and known moderators (e.g., differential experience with outgroups, differential motivation).

The model relies on two distinct but reciprocally influential mechanisms. First, shaped by expertise with ingroup faces, the perceptual system learns to emphasize certain visual patterns (and deemphasize others), distorting perception in a way that preferentially enhances individuated representations of ingroup members (perceptual enrichment). Second, experience shapes expectations about what faces should look like, novel faces are rapidly compared to this reference, and the result of that comparison biases subsequent processing (expectancy and reciprocal processing). The interplay of these two mechanisms is hypothesized to explain a variety of psychological biases, influencing early attention, classification, and individuation. A core theme of this work is that race assumes subjective importance not due to inherent biological or psychological significance, but because, as a culturally relevant dimension, it structures social interaction, which in turn affects perception and expectation.

2. Diverse effects of race on visual processing

Race shapes perception in profound and multifaceted ways. Racial cues guide attention, alter encoding, and promote classification (including the activation of category-based semantic and evaluative information). Certain processes are generally enhanced for members of the racial ingroup (same-race or SR faces); others are enhanced for members of the outgroup (cross-race or CR faces).

Individuation. Research consistently demonstrates race-based differences in participants' ability to individuate faces (Meissner & Brigham, 2001). Much of this work relies on episodic recognition tasks. Participants might be asked to view a set of faces (some SR, some CR) and, in a subsequent task, to distinguish these previously viewed faces from a set of never-before-seen lures. In general, recognition accuracy is better for SR faces than for CR faces. Similar patterns emerge from studies that rely on perceptual discrimination, in which a to-be-remembered face is briefly presented, followed quickly by an array of faces that includes the to-be-remembered face and several lures. Participants are typically better at identifying the to-be-remembered stimulus when the array is comprised of SR faces rather than CR faces. Relatedly, CR faces seem to induce less dynamic visual processing as measured by eye-tracking (Goldinger, He, Papesh, 2009).

Face classification. SR faces also enhance perceivers' ability to determine that a given stimulus is actually a face, in the first place. Valentine (1991) presented participants with intact and "jumbled" versions of several faces (the jumbled faces had been modified by rearranging the internal features). Participants were simply instructed to distinguish between intact and jumbled faces. He found that participants were quicker to classify an intact stimulus as a legitimate face when it was an SR face rather than a CR face.

Attention. Though processing of faces as individuals and legitimate faces may thus be enhanced for SR faces, other processes are facilitated for CR faces. Perceivers often devote greater attention to CR faces. Using exogenous cueing or dot-probe tasks, behavioral studies show evidence of preferential attention, suggesting that (for White perceivers) Black faces capture attention more quickly and/or hold attention longer than White faces (Correll, Guillermo, Vogt, 2014; Donders, Correll, & Wittenbrink, 2008; Trawalter, Todd, Baird & Richeson, 2008; see Guillermo & Correll, 2016, for similar evidence with Latino faces). Attention to CR faces seems to occur very quickly and can guide responses even to impoverished stimuli. Ito and Urland (2003, 2005) measured event-related brain potentials (ERPs) as White participants viewed White and Black faces. In response to CR faces, perceivers showed amplification of an early electrocortical fluctuation called the P200, which has been associated with visual attention. These data suggest that, as early as 200 ms after stimulus presentation, perceivers show more attention to racial outgroups. Similarly, Cunningham and colleagues (2004) presented faces very briefly (30 ms) and, among White participants, found increased activation of the amygdala in response to Black faces (relative to White faces). Much of the work in this domain (though not all, see Al-Janabi, Macleod, & Rhodes, 2012; Guillermo & Correll, 2016) involves White participants who are asked to view Black and White faces. This limitation should obviously be considered when evaluating the argument that perceivers (in general) attend to CR faces (in general).

Race classification. Finally, several studies have asked participants to categorize SR and CR faces by race. Participants routinely categorize CR faces more quickly and more accurately than SR faces (a phenomenon that has been called the cross-race classification advantage; Valentine & Endo, 1992; Levin, 1996). Again, this pattern can be observed even with impoverished stimuli. Correll, Hudson, and Tobin (2016) presented White participants with faces (either Black or White) and found that participants classified CR faces more quickly than SR faces. Further, the participants could do so based solely on low-spatial frequency images (in essence, blurry images).

Summarizing across domains of recognition, attention and categorization, evidence suggests that perceivers treat SR faces more as legitimate faces and as individuals, but less as members of a category. By contrast, in response to CR faces, they quickly orient attention and respond to the stimulus more as a “kind” (Levin, 2000; Sporer, 2001; cf. Park & Rothbart, 1982).

3. Explaining effects of race on face processing

Effects of race on social perception are so robust and so prevalent that race has been described as a fundamental dimension of interpersonal perception (Brewer, 1988; Fiske & Neuberg, 1990), as if it were a natural way to divide the world. But scholars have challenged the idea that humans are evolutionarily predisposed to attend to race or treat race as somehow more significant than other dimensions, like gender, age, language or even clothing (Cosmides, Tooby, & Kurzban, 2003; Olsson, Ebert, Banaji, & Phelps, 2005; see Kinzler, Shutts, & Correll, 2010, for a review). These writers note that the environment in which humankind evolved allowed for limited travel. Hunter-gatherers moved largely by foot, effectively precluding contact with geographically and genetically distant populations. The chance that a prehistoric hunter-gatherer in Asia, for example, would encounter anyone of a different *race* was vanishingly small. Unlike gender and age, which must vary in any viable group of hunter-gatherers, race would effectively be held constant. Why, then, would humankind develop cognitive systems dedicated to making sense of racial variation?

Rather than an evolved sensitivity to race, per se, human face-processing systems may have developed phylogenetically, over the course of millennia, to detect subtler differences, allowing the perceiver to distinguish between ethnic, tribal or family-based groups living in closer proximity – groups that all belonged to the same race.[1] For example, it may have been adaptive for the ancestors of the Tswana and Kalanga people in modern Botswana, or the Celtic Cotini and Germanic Quadi people in what is now Slovakia, to distinguish members of the outgroup from members of the ingroup. A perceptual system capable of detecting relatively subtle inter-tribal differences, a kind of family resemblance, would presumably respond powerfully to the pronounced physical differences between racial groups (e.g, if a member of the Black Tswana suddenly encountered a member of the White Cotini). In modern multi-racial societies, race may thus exert profound effects on interpersonal perception, giving the (incorrect) impression that race is a natural way to parse the social environment.

A critical point for the present argument is that race-based sensitivity to facial morphology may also develop ontogenetically, over the course of childhood and adolescence, as a function of experience, in a manner that parallels other developmental learning processes, like limb coordination, language, and the inference of intention.

Evolved systems of face perception may thus be tuned by individual experience, allowing the perceiver to appropriately classify faces, to individuate familiar types of faces (presumably members of the ingroup) and to orient attention to unfamiliar kinds (presumably members of an outgroup).

We hasten to note that, while expertise and learning may play critical roles, it is almost certainly the case that the effects of race on face processing reflect a variety of psychological processes. Explanations based on several factors have been explored, though these research programs vary in terms of their scope and the empirical support they have uncovered. Some explanations attempt to account for multiple phenomena (recognition and attention); others seem primarily applicable to a single phenomenon. We focus on four potential explanations: race-based attitudes (stereotypes and prejudice), motivation, the idea of a *race-specifying feature,* and differential experience. Each of these explanations has compelling empirical support, but each also has logical or empirical problems. We will ultimately conclude that no single explanation can account for the diverse effects of race on face processing. (To be both fair and clear, most proponents would probably never claim that a single explanation can or should account for effects as diverse as attention, individuation and classification. But the current paper offers a model designed to account for the broader set of effects, and we evaluate the explanations in that light.)

a. Attitudes (to explain attention and individuation)

Racial groups are associated with a host of affective and semantic associations. People often show evidence of greater positivity toward racial ingroups than toward racial outgroups, and toward dominant or reference groups in society. In addition, whether a group is viewed positively or negatively, it may be associated with a multifaceted set of semantic information. These associations, both evaluative and semantic, may guide face processing.

In many of the studies examining race and attention, enhanced attention to a CR face is thought to derive from associations between the outgroup and danger. Many of these studies ask White perceivers to view White and Black faces. In as much as Black people are stereotypically associated with danger in US culture, it has been argued that attention to the CR (Black) faces may derive from evolutionary processes related to threat detection (Ohman, Flykt, & Esteves, 2001). Research does suggest that attention to CR faces is more pronounced when threat-based stereotypes are accessible (Correll, Guillermo, & Vogt, 2014; Donders et al., 2008; Trawalter et al., 2008), but threat may not be necessary to induce attention to CR faces. Al-Janabi and colleagues (2012) tested White female participants and observed preferential attention to Asian (rather than White) female faces. Importantly, this pattern of preferential attention emerged even though the Asian faces were rated as no more threatening than the Whites. Al-Janabi suggested that, even in the absence of threat, CR faces are unfamiliar and may be sufficient to induce preferential attention.

It also seems plausible that attitudes might influence face recognition or classification. For example, a perceiver may be less likely to individuate a member of a racial outgroup that is seen as low in status and warmth (Harris & Fiske, 2006; Operario & Fiske, 2001). But the evidence that attitudes affect face recognition is fairly weak. Ferguson, Rhodes, Lee, & Sriram (2001) reviewed the literature and failed to find clear evidence of an association between prejudice and racial bias in face recognition. The authors, themselves, also report null effects of both implicitly and explicitly measured attitudes. To the extent that any relationship between evaluation and face recognition does exist, it may be mediated by the factor we consider next, motivation.

b. Motivation (to explain individuation)

Hugenberg and his colleagues argued that deficits in CR face recognition stem, at least in part, from reduced motivation to individuate members of an outgroup. The strongest form of this argument is that people have equal ability to process CR and SR faces but do not invest effort when processing the outgroup because it is not personally relevant. Researchers have examined this question from two different logical perspectives. The first perspective offers compelling evidence that *reducing* motivation can impair face recognition (Bernstein, Young, & Hugenberg, 2007; Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008). These studies typically involve White participants and present only White (SR) stimuli. Half of the SR targets are designated as members of an ingroup (e.g., students attending the same school as the participant), and the others are designated as members of an outgroup (e.g., students at a different school). This manipulation can be accomplished simply by pairing each face with a visual cue that indicates group membership. For example, ingroup faces might be embedded in a colored rectangle indicating the home school color, and outgroup faces might be embedded in the color of a rival school. Stunningly, this simple manipulation leads to deficits in face processing that mirror the CR recognition deficit. Recognition accuracy is impaired for the outgroup, as is holistic processing. Conceptually similar work involves a standard set of faces that is made to seem more like SR faces or more like CR faces by altering their hair style (Maclin & Malpass, 2003) or social context (Schutts & Kinzler, 2007). In either case, recognition suffers for the outgroup (but see Rhodes, Lie, Ewing, Evangelista, & Tanaka, 2010). Perceptual expertise cannot explain these effects: in this work, stimuli are randomly assigned to the ingroup or outgroup, so participants should have equal familiarity with the features of both groups. The researchers generally argue that the performance decrement stems from reduced relevance of (and motivation to process) the outgroup.

In a second line of argument, researchers effectively test the inverse relationship. Does *increasing* motivation improve individuation? These studies usually involve White perceivers viewing both White and Black faces. They test whether motivation can eliminate the CR recognition deficit that is otherwise observed. In a typical study, participants are told, “pay close attention to what differentiates one particular face from another face of the same race, especially when that face is not of the same-race as you” (Hugenberg, Miller, & Claypool, 2007). The results of several studies suggest that this manipulation reduces or eliminates the CR recognition deficit. This work is compelling in many ways, but in our view (compared to the nominal outgroup work described above), the findings offer weaker support for the role of motivation in the CR recognition deficit. In this paradigm, participants are (a) warned about a performance deficit, (b) instructed to try to overcome it, and (c) given a strategy to achieve this goal by paying attention to “what differentiates one particular face from another.” The manipulation thus introduces confounds associated with knowledge and strategy. Accordingly, the mechanisms by which this manipulation improves recognition are not clear. Perhaps CR recognition improves because motivated participants employ the kind of processing operations they normally apply to SR faces. But it is also possible that perceivers shift processing strategies (e.g., devoting greater attention to distinctive features in CR faces). In our view, then, existing work offers strong support for the proposition that reducing motivation interferes with the kind of processing that typically characterizes SR faces, but less conclusive support for the idea that increased motivation promotes ingroup-like processing for faces that do not receive it by default (Hehman, Mania, & Gaertner, 2010).

c. Race-specifying features (to explain attention and individuation)

Levin (1996; 2000; Levin & Angelone, 2002) suggested that CR faces contain a *race-specifying feature* that is not present in SR faces. Levin did not exactly define what visual properties convey this race-specifying feature, but his logic derived from the concept of outgroup homogeneity (Linville, Fischer, & Salovey, 1989; Park & Rothbart, 1982), which suggests that outgroup status provides more information to a perceiver than ingroup status. One interesting implication of this perspective is that CR faces are thought to be *feature-positive* stimuli. The idea is not simply that the ingroup has feature A and the outgroup has feature B. Rather, the ingroup is perceived as feature-negative (they do not have a meaningful race cue for the perceiver); only the outgroup has the race-specifying feature. If this is true, theories of attention suggest that CR faces should "pop out" in an array of distractors and attract attention in a manner that faces without such a feature do not (Treisman & Gormican, 1988). Another implication of this perspective, also derived from existing theories of attention as a limited resource (Broadbent, 1958; Deutsch & Deutsch, 1963; Lavie, 1995; Treisman, 1969; Nosofsky, 1986), is that increased attention to the race-specifying cue should reduce the availability of attention for other information in the face. Because perceivers attend to race-specifying information in CR faces, they may thus fail to attend to individuating features that would otherwise allow them to differentiate one CR face from others. For example, when White perceivers view White and Black faces, they may attend to nose length. In fact, nose length seems to vary dramatically between groups: on average, White faces have longer noses and Black faces have shorter noses (Ma, Correll, & Wittenbrink, 2015; Correll, Ma, & Kenny, 2016). Accordingly, a White perceiver might reasonably employ a shorter nose as a cue that the face belongs to the outgroup. But nose length does not vary as dramatically within Black faces groups (and so does not offer a cue that reliably distinguishes one Black face from another). By attending to nose length, a White perceiver may therefore fail to encode other cues (e.g., eye height or eye width) that would facilitate individuation of a specific Black face (see Figure 1; Correll, Ma, & Kenny, 2016).

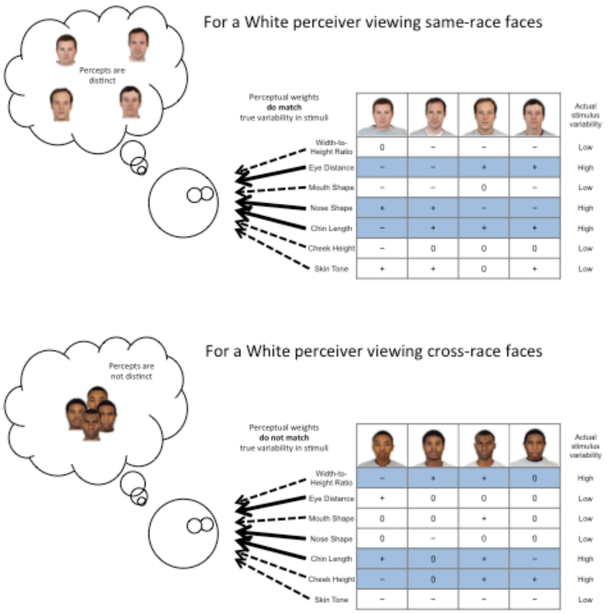

Figure 1. Differential perceptual weighting of same-race and cross-race faces, such that perceptual weights of same-race faces correspond to actual variation in facial features, thus facilitating individuation.

Levin (2000) marshaled support for an attention-based account by asking predominantly White participants to perform two separate tasks. One task examined the extent to which a Black face “pops out” from a set of distractors, the way a red dot might pop out from a set of green dots. Participants viewed a series of arrays of faces that had been standardized in terms of low-level properties like luminance and contrast. In one block of trials, they were asked to determine whether or not a Black face was present. Arrays of faces ranged in size from 2 to 4 to 8, and were either comprised entirely of

White faces (no Black faces), or included a single Black face amid White distractors. In a different block of trials, participants were asked to determine whether or not a White face was present among Black distractors. The idea behind this task was that, if Black faces contain a distinctive race-specifying feature (a feature that is not present among White faces), participants should detect the Black face quickly, and increasing the size of the array should not slow them down much. By contrast, speed to detect a lone White face should be compromised by a larger array. And that is exactly what Levin found. A lone Black face in an array of White faces was more likely to pop out than was a lone White face in an array of Blacks, even when controlling for skin tone. This pattern supports the idea that participants preferentially attend to CR faces, but also that there is some cue in CR faces that is absent in SR faces (i.e., CR faces are feature positive). Levin also tested recognition of White and Black faces for this same group of participants. As he predicted, participants who showed especially pronounced pop-out effects for a lone Black face also had more trouble recognizing Black faces. He argued that, because perceivers attend to race-specifying features, they fail to attend to other information that might otherwise allow them to individuate CR faces. In a follow-up study, he cleverly extended this argument by developing a stimulus set in which race-specifying features *were diagnostic* of individual identity. In these stimuli, Black faces could be most effectively individuated by the very features that typically specify race (features that differentiate Black faces from White faces). Stunningly, but as he predicted, participants who demonstrated poor recognition of Black faces in a normal test were indeed *better* at identifying Black faces in the new stimulus set. Presumably, these participants typically attend to race-specifying cues, and (in the new stimulus set) those cues were actually advantageous for identification. As striking as this evidence seems, it is worth noting that subsequent work has failed to replicate the results (Walker & Tanaka, 2003).

The idea of a race-specifying feature nicely accounts for several phenomena. It essentially proposes a causal link: preferential attention (and perhaps the CR classification advantage) is thought to induce the CR recognition deficit. Studies showing that racial outgroups attract attention (discussed above) are generally consistent with a race-specifying feature account (Al-Janabi et al., 2012; Donders, et al., 2008; Ito & Urland, 2003, 2005).

It is worth acknowledging that this pattern of findings may seem counterintuitive. The argument here is that enhanced attention causes poorer memory. But most studies of attention and memory show that attention aids recognition. The critical issue, of course, is that, according to Levin, attention is directed to the *wrong kind of cues* – cues that effectively lump all CR faces into an undifferentiated pool. Enhanced attention to such cues may lead to deficits in recognition.

d. Experience and expertise (to explain individuation)

Perhaps the most frequently-discussed account of race-based differences in visual processing involves the argument that perceivers have more contact with the racial ingroup and therefore more expertise with SR faces. Through experience, perceivers arguably learn to process SR faces in a qualitatively different way.[2] This perspective is fundamental to the current paper, and we will explore its implications in the remainder of this section and in the sections below. Here, we provide a brief review.

Critical evidence for the expertise account comes from developmental research that examines changes in face processing during childhood. Human beings do not enter the world predisposed to preferentially perceive and encode SR faces, or to preferentially orient attention to CR faces. Prior to the age of 3-6 months, infants respond similarly to both SR and CR faces. White infants, for example, can reliably discriminate between two different White faces, but they are equally proficient with two different Asian faces. Young infants can even discriminate between the faces of macaque monkeys (Kelly, Quinn, Slater, Lee, Ge, & Pascalis, 2007; Sangrigoli & de Schonen, 2004). This egalitarianism is short lived, however. Between the ages of 3-12 months, even though infants retain the ability to differentiate SR faces, they lose the capacity to differentiate faces of other races (and other species). This loss of sensitivity seems to be a direct consequence of a lack of individuated experience with the outgroup. In a set of clever studies, researchers prepared picture books containing faces of a racial outgroup (Heron-Delaney, Anzures, Herbert, Quinn, Slater, Tanaka, Lee, & Pascalis, 2011) or of macaque monkeys (Scott & Monesson, 2009). Some infants were regularly shown a book of CR/monkey faces, while others were not. Without exposure to the book, infants gradually lost sensitivity to CR or cross-species faces. But infants who viewed the picture books retained the ability to differentiate those faces. These results suggest that exposure to otherwise unfamiliar faces enhances sensitivity. It is important to note that the efficacy of the picture-book manipulation actually required *individuation,* not just exposure. The picture book had little effect unless it included names for each face, presumably prompting the infants to consider the faces as individuals rather than as indistinct members of a category (Scott & Monesson, 2009). Through individuated exposure, then, infants maintained sensitivity to patterns of facial variation. They only lost sensitivity to variation that was absent from, or irrelevant to, their social environment.[3]

One interesting aspect of this research is that it suggests that the CR recognition deficit may emerge not only because SR processing improves, but also because CR processing atrophies. Though this work compellingly demonstrates the influence of individuated exposure, the pattern deviates from other work on practice and fluency in which training improves perception (e.g., Gauthier & Tarr, 1997). Infants' loss of sensitivity to CR faces may be more similar to the process of language learning (where infants lose the ability to distinguish phonemes that are absent from their native language) than to the process of developing expertise with birds or cars, in which exposure improves performance with the focal category.[4]

Other studies have examined young adult participants (typically undergraduates) who report high or low levels of CR contact. In this work, it is often unclear exactly when the contact took place (e.g., early or late childhood), but more extensive contact with CR faces is often associated with improvements in recognition (Chiroro & Valentine 1995; Hancock & Rhodes, 2008; Walker & Hewstone, 2006).[5]

In an influential paper exploring the effects of differential contact and expertise on face processing, Valentine (1991) described the mental representation of faces in terms of a *multidimensional face space*. He suggested that this space includes faces that an individual has previously seen, and that these faces are arrayed in the space according to their characteristics. Two similar faces (e.g., two brown-eyed, baby-faced White male faces) should be close to one other in the space. Faces that differ in particular features should be farther apart on the relevant dimensions (e.g., a *blue*-eyed, baby-faced White male might be close to the others on dimensions of face shape, but far on dimensions of eye color). The more distant two faces are in the face space, the easier it should be to distinguish between them. Valentine suggested that the center of this multidimensional space (the average of all the faces the perceiver has seen) serves as a kind of expectation about what faces usually look like. We will refer to this expectation as the perceiver's *face reference*. Some researchers have attempted to determine whether or not the perceiver actually generates an abstract mental representation (a prototype) at this point, or whether the space consists entirely of exemplars in memory (e.g., Rhodes, Brennan & Carey, 1987; Rhodes, Jeffrey, Watson, Clifford & Nakayama, 2003; Valentine & Bruce, 1986). For the purposes of the current argument, the distinction between exemplar- and prototype-based representations is not important (indeed, they may not be empirically distinguishable; Jäkel, Schölkopf, & Wichmann, 2009). Our argument relies only on the idea that there is some reference point, which represents the central tendency of faces that the perceiver has encountered. Valentine's argument was that, if faces deviate dramatically from the face reference, they should seem unusual or non-face-like. He tested this idea using the face-classification task described above, in which participants are asked to distinguish between intact and jumbled face stimuli. In one relevant study, he began with two sets of SR faces, one normal-looking set and one set of distinctive faces (raters indicated that the latter would stand out in a crowd). Valentine found that participants were quicker to identify an intact face if it was normal rather than distinctive. He interpreted this difference as evidence that distinctive faces (even when they were intact) were less similar to the face reference, and accordingly, seemed less like legitimate faces to the participant. Valentine ultimately suggested that SR faces are prevalent and centrally located (tending to define the reference), and widely dispersed in the face space (allowing individuation of exemplars). By contrast, he suggested that CR faces are rare and far from the center of the space (leading perceivers to view them as atypical) as well as densely clustered (leading to confusion between exemplars). A core aspect of Valentine's model is that the face space is constructed, based on the faces that the perceiver encounters throughout life. Accordingly, experience matters. Exposure to an Asian environment means that the face space will be populated primarily by Asian faces. Exposure to a White environment means that the space will be populated by White faces. By changing the face space, exposure may change face processing.[6]

A number of studies offer support for the idea that perceivers generate and make use of a mental average (a face reference) based on exemplars to which they are exposed. After viewing a diverse set of faces, 3-month-old infants seem to compute a mental average of the stimuli. Subsequently, when they are presented with an average face (created by morphing the previously viewed faces together), the infants treat it as familiar even though, in truth, they have never seen that face before (de Haan, Johnson, Maurer, & Perrett, 2001). Moreover, eight-year-old children and adults (who are White) show evidence of a White face prototype, against which they implicitly compare exemplars (Leopold, O'Toole, Vetter & Blanz, 2001; Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008).

Naïvely, it seems plausible that experience and perceptual expertise should be related to several of the phenomena we have examined in this paper. There have been a great many studies examining the effects of perceptual expertise on the CR recognition deficit. But to our knowledge, relatively little work has directly examined the effects of perceptual expertise on face classification, preferential CR attention or the CR classification advantage. Valentine (1991) certainly makes the theoretical argument that classification of CR faces *as faces* suffers as a function of their unfamiliarity, and he offers some correlational evidence. With respect to CR attention, Al-Janabi (who, as mentioned above, found evidence of preferential attention to non-threatening Asian faces) argued that CR faces attract attention because they are unfamiliar – an argument that obviously relies on the idea that perceivers have minimal contact with racial outgroups. We have also examined individual differences in CR contact. In partial support of the idea that contact can reduce CR attention, we found that White participants who reported higher levels of contact showed reduced amygdala activity when presented with Black faces, though this pattern emerged only for Black faces that had been viewed earlier in the study (Cloutier, Li, & Correll, 2014). And a recent study found that White participants reporting higher levels of contact with Blacks (in one study) and Asians (in a second study) showed less preferential attention to these outgroups (Dickter, Gagnon, Gyurovski, & Brewington, 2015).

Summary and relationships between the accounts

Disentangling accounts based on attitudes, motivation, race-specifying features and perceptual expertise is difficult for several reasons. First, the four accounts are not typically been applied to a common set of phenomena. Generally, attitudes have been offered as an explanation of attention, and motivation has been offered as an explanation of individuation. Race-specifying features involve both attention and individuation, and expertise has been applied, chiefly, to classification and individuation. Clarity is also difficult because greater experience individuating CR faces (the crucial variable in terms of perceptual expertise) may (a) alter attitudes, (b) reduce the likelihood that a participant attends to category information (which is critical for the race-specifying feature account) and/or (c) increase the participant's motivation to individuate the face. Although it is possible to manipulate attitudes, categorization and motivation while holding expertise constant, it is thus difficult to manipulate expertise without introducing these potential confounds. The stereotyping, race-specifying feature, and motivation accounts may also be related. Classification is often viewed as a precursor to stereotyping (cf. Blair, Judd, Sadler, & Jenkins, 2002). And classifying a face as a member of an outgroup (rather than an ingroup) may reduce participants' motivation to process it in an individuated fashion. Finally, motivation to process individuating features (rather than categories) may have implications for attention to category cues and stereotype activation (e.g., Brewer, 1988; cf. Ito & Urland, 2005).

All the same, distinctions between these accounts do exist, and those distinctions provide some theoretical and empirical leverage. In particular, extensive contact and expertise should affect both the nature of the percept engendered by a face stimulus (which may be more or less rich in individuating information), as well as the nature of the perceiver's face reference. To begin this exploration, we consider what *race* actually represents, how it is related to morphological differences in faces, and how it constrains social interaction. These are crucial points because, logically, expertise should only promote differential race-based processing to the extent that (a) perceivers preferentially interact with members of their racial ingroup, and (b) in doing so, they are exposed to patterns of SR facial morphology that differ in meaningful ways from the morphology of CR faces.

4. Segregation & facial morphology (cause & consequence)

In this section, we present evidence that the prehistoric environment (in which human face processing developed) was characterized by profound geographic segregation that gave rise to differences in facial morphology. In turn, today, differences in morphology (which we call race) constrain human social interaction through social segregation. As a consequence, (a) perceivers interact more frequently with SR conspecifics who are (b) characterized by a particular set of facial features.

Anthropologists and archaeologists have provided strong support for the idea that geographic separation promoted differences in facial appearance, which correspond to our modern conceptualization of race.[7] Over the course of the last two hundred thousand years, humankind is thought to have emigrated from Africa and spread across the planet (Cann, Stoneking, & Wilson, 1987; Vigilant, Stoneking, Harpending, Hawkes, & Wilson, 1991). With geographic separation and the consequent development of distinct breeding populations, a combination of processes, including mutation, genetic drift and natural selection, gradually fostered genetic and phenotypic diversity. Research in human population genetics shows geographically patterned clustering of variation in the human genome (Cavalli-Sforza, 1991; Tang et al, 2005; see also Rosenberg et al., 2002) and suggests nine putative human subpopulations that can be grouped into four broader clusters associated with (a) Africa, (b) Europe, (c) East Asia and America, and (d) Oceania (i.e., the Pacific Islands, Australia, South Asia). Physical measurements of the human skull suggest parallel differentiation in the phenotype, with geographically and genetically distant subpopulations generally showing more extreme differences in morphology (Relethford, 2010; Manica, Amos, Balloux, & Hanihara, 2007; Wright, 1943). For example, physical differences in the morphology of both the upper face and mandible are strongly correlated with migratory distance (i.e., the distance required to travel from one subpopulation to the other) (Betti, Balloux, Amos, Hanihara, & Manica, 2009; Smith, 2011).[8]

Any two distinct breeding populations should develop distinctive morphology over time, even if they live in close proximity and encounter similar environmental challenges. To the extent that individuals of each group reproduce exclusively with other ingroup members, random genetic changes that emerge in one group will not propagate to the other. The magnitude of intergroup differentiation may be large or small depending on the degree and duration of exclusive reproduction (Wright, 1943). Pronounced differences, such as differences between Chinese and French (which correspond to the modern concept of race), reflect almost complete separation of breeding populations for hundreds of thousands of years. Subtler differences, such as differences between Chinese and Mongolians, French and Russians, Hopi and Sioux, or Hutu and Tutsi, may reflect shorter periods of separation or partially overlapping breeding populations. The critical aspect of this argument is that long-standing divisions between breeding populations, including divisions based on geography, gave rise to *objective, physical variation in the human face* (which corresponds, imperfectly, to the cultural concept of race).[9]

Today, these objective differences in appearance promote and maintain social segregation. During the last millennium, geographic segregation has given way to increasingly integrated populations. Technology has allowed people to travel farther and faster, and migration (forced or voluntary) has created communities in which genetically distant individuals live in close proximity. But race still structures social interaction. Even in a multicultural society like the US, where opportunities abound for interracial contact, interracial marriage and multiracial children, racial segregation is still the norm: most people interact more extensively and intensively with people who belong to their own racial group.

The Census Bureau computes several indices that reflect the degree of residential integration/segregation in US neighborhoods. For our purposes, the most relevant measures of segregation involve *evenness* and *exposure*. Evenness reflects the proportion of a given population (e.g., Blacks or Latinos) that would have to move to a new neighborhood to ensure that every neighborhood in a metropolitan area had an equal proportion of that group. Exposure measures the degree to which members of a given race or ethnicity are exposed only to each other. These indices vary from 0 (complete integration) to 1 (complete segregation). A report based on data from the year 2000 showed that, although both indices decreased in recent decades, segregation is still the norm (Iceland, Weinberg, & Steinmetz, 2002). Evenness measures for Blacks, Latinos, and Asians (respectively) were 0.846, 0.754, and 0.505. Respective exposure measures were 0.827, 0.952, and 0.832. These scores clearly reflect a segregated population, even though that segregation is no longer maintained by geography or law.[10] Racial differences in appearance or phenotype (differences that were generated by the geographic separation of human ancestors over 200 thousand years) thus provide a basis for the ongoing segregation of society. Race still constrains interaction.

To the extent that (a) people typically interact more frequently and intensively with members of a single racial group (and less frequently and less intensively with members of other racial groups) and (b) those racial groups differ in physical appearance, experience and expertise should engender specific biases in visual processing. In the sections below, we examine two potential consequences. Section 5 considers perceptual enrichment, whereby the visual system learns to selectively prioritize and integrate certain kinds of perceptual information (expertise). Section 6 examines the way that contact (or experience) shapes expectations for faces, and the way those expectations influence perceptual operations through a process called *predictive coding*. After introducing these two distinct processes, we present an integrative model that attempts to account for their combined effects.

5. Perceptual Enrichment

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Comment [1]: here might be a good place to give a quick recap, before moving to the next part of the paper which i read as more the model portion. "so far we have argued that …." before you start moving to the

By definition, segregation means that perceivers encounter the ingroup more frequently than the outgroup. And differential expertise with any class of stimuli can promote changes in visual processing that help the perceiver distinguish among exemplars of that class. For example, detection of well-defined targets in arrays of letters and numbers becomes faster and more accurate with practice (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Expertise also facilitates discrimination of stimuli that vary in configuration, such as arrangements of chess pieces (Chase & Simon, 1973; de Groot & de Groot, 1978), models of car and species of bird or dog (Tanaka & Taylor, 1991), and *greebles* (artificial face-like stimuli; Gauthier & Tarr, 1997). An individual who must repeatedly differentiate between bird species, for example, develops greater sensitivity to dimensions that meaningfully differentiate exemplars, and comes to de-emphasize dimensions that do not. Expertise also promotes the construction of holistic, integrated representation of bird stimuli. As a consequence, with practice, the perceiver comes to represent these stimuli in a way that is richer in judgment-relevant information.

The putative visual word form area (VWFA; McCandliss, Cohen, & Dehaene, 2003) provides a useful analog of the kind of visual processing we ultimately want to explore with faces. It also nicely demonstrates the influence of expertise. The VWFA is a region of the ventrotemporal cortex, typically in the left hemisphere of the brain. As its name suggests, the area is thought to generate an abstract representation of visually presented (printed) words. Among literate adults, the VWFA seems to prioritize features of words that are essential for the task of reading, namely, lexical identification. It is sensitive to the shape of letters and their sequence, but it is relatively insensitive to features that are not critical for reading (e.g., font, case or size of the typeface). Bluntly, McCandliss and colleagues argue that this region weights features as a function of task relevance, and integrates them to form a representation that highlights the subjectively important information in the stimulus. Moreover, the system is trained through experience. Though preferential weighting of reading-relevant features is evident among literate adults (who have expertise differentiating one word from another), it does not characterize processing for illiterate adults or children who have not yet mastered reading.

In a similar fashion, greater expertise with ingroup members should lead to a richer representation of identity diagnostic information in SR faces (and a de-emphasis of information that is not diagnostic for SR faces, potentially leading to impoverished representations of CR faces). Our discussion focuses on the idea that expertise promotes (a) perceptual learning, or the selective weighting of some (but not all) visual information in a face, and (b) the effective integration of those (weighted) features to generate a holistic representation of the face. We will explore the neural substrates and cognitive consequences of these processes, and highlight the role of expertise in each.

a. Perceptual learning

Traditional theories of visual perception suggest that sensory information propagates in a bottom-up fashion from early visual areas in the occipital cortex (involved in the detection of rudimentary features, like edges) to more anterior, temporal areas that integrate those perceptual fragments into a coherent whole (Van Essen & Maunsell, 1983). Thus, processing proceeds from local and concrete to global and abstract. But the nature of this bottom-up propagation changes with experience. Perceptual learning involves the idea that, with repeated exposure to a particular kind of challenge, the perceptual system actively restructures itself. Based on feedback from previous trials, the brain adjusts or reweights the neural connections in ways that increase sensitivity to judgment-relevant differences among the stimuli (and/or reduce noise; Ahissar & Hochstein, 2004; Dosher & Lu, 1999). In an experiment, participants might be asked to determine whether a briefly presented stimulus (e.g., a Gabor patch) is tilted slightly to the left or slightly to the right. This is not a cognitively or behaviorally challenging task. Still, with practice, performance increases. The reason is that the perceptual system changes in ways that accentuate whatever visual information is relevant for the decision (in this case, orientation).

Perceptual learning may involve changes to connections between areas involved in early visual perception (well before the brain integrates information into a unified representation). It may also involve reweighting of connections at the point of integration, allowing diagnostic information to exert greater influence as a unified percept is constructed (Dosher & Lu, 1999; see Watanabe & Sasaki, 2015, for a review). There is evidence that connectivity within early visual processing areas (V1 and V2) is altered by training, however these changes seem to be very specific to the training situation. For example, learning seems to be specific to the exact location in the visual field where training took place – it does not generalize. Perceptual learning may also occur at middle stages of processing involved in perceptual integration (V3, V4, middle temporal areas) or even late stages that involve deliberative processing (anterior cingulate, prefrontal cortex). Learning at mid or late stages seems to be more flexible and likely generalize across location and stimulus. From our perspective, mid-stage perceptual learning is particularly interesting because it likely corresponds with activation in the ventrotemporal cortex (discussed below in reference to integrative processing).

Perceptual learning should occur when an individual routinely differentiates between faces of one racial group (e.g., Asians) but rarely differentiates between faces of other racial groups. For the familiar group, perceptual learning should help the perceiver extract visual information that helps identify faces as distinct individuals. But if members of other racial groups vary along different physical dimensions,[11] perceptual learning also suggests that the perceptual system will be poorly calibrated to detect that variation. The perceiver may thus fail to extract valuable individuating information from members of an unfamiliar group, so those individuals may be perceived as relatively homogenous (see Figure 1; Ma, Correll, & Wittenbrink, 2015).[12]

The relevance of perceptual learning for race-based processing has been explored in interesting ways through computer simulation. Using machine learning to simulate the effects of expertise, Abdi and colleagues (Caldara & Abdi, 2006; O'Toole, Deffenbacher, Abdi, & Bartlett, 1991) showed that perceptual learning can generate aspects of the CR recognition deficit. In this work, a neural network was trained with either Asian or White faces, as if it were "raised" in a homogenous racial environment. The model was then tested with both Asian and White faces to see how it would perform with, essentially, SR and CR faces. A system trained with Asian faces "recognized" Asian faces better than Whites, and (as Valentine, 1991, might have predicted) represented Asian faces as more widely dispersed and differentiated than White faces in a multidimensional space. The system trained with Whites did the opposite. In research with human participants, White participants were asked to practice individuating members of one outgroup (e.g., Blacks) but to process members of a different outgroup (e.g., Asians) in a way that did not require individuation. Consistent with perceptual learning, performance on both a recognition task and a perceptual discrimination task improved for novel CR faces from the individuated group, but not for faces from the other group (Lebrecht, Pierce, Tarr, & Tanaka, 2009; McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2010).

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Comment [2]: should you use "as proponents of perceptual expertise might predict" then cite Valentine?

b. Integration of visual information

Perceivers do not typically view faces as collections of independent parts. Rather, face perception is characterized by sensitivity to relationships between features as well as by gestalt, holistic representation. Maurer, Le Grand and Mondloch (2002; but see Riesenhuber, Jarudi, Gilad, & Sinha, 2004) distinguish between first- and second-order relations. First-order relations refer to the standard organization of features in a face (two eyes above a nose above a mouth – the sort of relationships that are jumbled in Valentine's face classification task). Second-order relations refer to subtler changes in spacing (e.g., wider-set vs. narrower eyes). These authors also suggest that configural representation of either order can be distinguished from *holistic processing*, by which the visual system assimilates the nose, mouth, eyes, and other discrete features into a unified, gestalt representation. This integrated representation seems to facilitate recognition of the face as a whole, but can actually impair the perceiver's ability to recognize individual features (Galton, 1883; Richler, Cheung, & Gauthier, 2011; Wang Li, Fang, Tian, & Liu, 2012). A feature, such as Jenny's nose, looks different when it appears in the context of Sarah's face. Perceivers have trouble seeing the nose in isolation because it becomes an integrated part of a new face.

Faces preferentially activate a distinctive network of regions in the brain that includes (but extends beyond) the ventrotemporal cortex. This "core" face processing network includes areas in the lateral inferior occipital gyri (which has been referred to as the occipital face area) and two regions of the temporal lobe: the lateral fusiform gyri in the ventrotemporal cortex (which has been referred to as the fusiform face area) and the posterior superior temporal sulci (Haxby, Hoffman, & Gobbini, 2002; Kanwisher, McDermott, & Chun, 1997), which may respond to inflexible and flexible characteristics of faces, respectively (e.g., identity vs. eye gaze or emotional expression; Bruce & Young, 1986; Hasselmo et al., 1989; Hoffman & Haxby, 2000). Activity in both temporal areas has also been linked to a negative voltage deflection in electroencephalographic activity that occurs roughly 170 ms after face presentation – an event-related brain potential (ERP) component called the N170 (Deffke, Sander, Heidenreich, Sommer, Curio, Trahms, & Lueschow, 2007; Itier & Taylor, 2004). But critically, integration of identity-relevant (inflexible) visual features in faces seems to be subserved by the ventrotemporal cortex (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Zhang, Li, Song, & Liu, 2012). This parallels the VWFA's ventrotemporal integration of lexical information.

Whereas the integration of lexical information is typically lateralized to the left hemisphere of the brain, integration of information in faces is generally lateralized to the right (Rossion, 2014). Studies using a wide variety of techniques (functional imaging, ERPs, lesions, behavior) suggest that (a) face processing induces greater activity in the right fusiform gyrus, (b) presentation of a face generates a larger N170 on the right (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Rossion, Joyce, Cottrell, & Tarr, 2003), (c) deficits in face processing (e.g., prosopagnosia) can follow from unilateral damage to the right temporal lobe (De Renzi, 1986; Landis, Cummings, Christen, Bogen, & Imhof, 1986), (d) participants are faster and more accurate responding to faces presented to the left visual field (LVF), which projects to the right hemisphere of the brain (Dien, 2009; McCarthy, Puce, Gore, & Allison, 1997), and (e) electrical stimulation of face-selective regions in the right (but not the left) hemisphere impacts face processing (Rangarajan, Hermes, Foster, Weiner, Jacques, Grill-Spector, & Parvizi, 2014).

As discussed above, effects of race can be hard to interpret because they may stem from differences in expertise, motivation, categorization or attitudes. Still, several findings are at least consistent with the argument that expertise with the racial ingroup biases the process of integration in a way that leads to better integration of familiar SR faces. Relative to CR faces, SR face perception is often characterized by increased holistic and configural processing (Michel, Caldara, & Rossion, 2006a; Michel, Rossion, Han, Chung, & Caldara; 2006b; Rhodes, Brake, Taylor & Tan, 1989; Tanaka, Kiefer, & Bukach, 2004), as well as by a more pronounced pattern of right lateralization (Correll, Lemoine, & Ma, 2011; Turk, Handy, & Gazzaniga, 2005). And, during a typical face-viewing task, participants show enhanced activity in the ventrotemporal cortex and a larger N170 when viewing SR rather than CR faces (Golby, Gabrieli, Chiao, & Eberhardt, 2001[13]; Senholzi & Ito, 2012).

A more rigorous test of the idea that expertise, per se, promotes integrative processing is found in studies that measure or manipulate contact with CR faces. In line with our argument, increased expertise with the outgroup promotes integration-related changes, including increases in holistic and second-order configural processing (Bukach, Cottle, Ubiwa, & Miller, 2012; Hancock & Rhodes, 2008), individuation (Cloutier et al., 2014), and lateralization to the right hemisphere (Davis, Hudson, Ma, Kheterpal, & Correll, 2015).

Summary

With extensive practice individuating faces of a given racial group, research suggests that the visual system learns (a) to more effectively extract individuating information, prioritizing dimensions of physical variation that meaningfully differentiate those faces, and (b) to more fully integrate this information into a unified perceptual representation. In combination, we suggest that these processes yield a percept that is rich in individuating information when the face belongs to a familiar (SR) group, but a relatively impoverished representation when the face belongs to an unfamiliar (CR) group.

6. Expectancy & reciprocal influence

Racial segregation also means that perceivers will typically perceive and encode a greater number of SR faces than CR faces. SR faces will therefore be more prevalent in memory. Valentine (1991) argued that exemplars in memory are dispersed in a multidimensional space, the center of which represents a kind of expectation or conceptualization of a "normal" face – an expectation we are calling the face reference. Because (a) the store of exemplars defines this norm, (b) those exemplars typically include more SR than CR faces, and (c) SR and CR faces differ morphologically, the reference should be biased toward the features of the racial ingroup.

In a slight extension of Valentine's argument, we propose that this cache of face exemplars likely shapes expectations about both the central tendency of faces, and also about the degree of normal variation. This expectation might be conceptualized as an estimate of the variance or standard deviation of previously viewed faces. As an illustration, consider an individual who experiences a mono-racial environment (attending a segregated school or growing up in a town where the vast majority of residents belong to a single race, like Bangor, Maine, 95% White in 2010; Lee, Iceland, & Sharp, 2012). In addition to conceptualizing an average face (the central tendency) largely in terms of White features, this individual may expect only minimal variation around the norm (a small standard deviation). By contrast, a perceiver exposed to a multi-racial environment (an integrated school, or a city like Vallejo, California, 41% White, 14% Black, 24% Hispanic, 15% Asian) might develop a very different representation of both the central tendency and the degree of normal variation around that average (a large standard deviation). We suggest that estimates of central tendency combined with variability reflect the perceiver's expectations about what a normal face looks like. Together, they may give rise to a sort of multidimensional latitude of acceptance for "normal" faces. Stimuli with features and configurations that, collectively, fall close enough to the face reference in the face space should be perceived as normal. Faces outside this latitude should violate expectations.

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Comment [3]: here is one of the places you might make a prediction (like we talked about sprinkling more predictions throughout)

a. Predictive coding and top-down influence

We suggest that expectations about "normal" faces (based on the perceiver's history of exposure) affect face perception through a process called predictive coding (Friston, 2005; Friston & Kiebel, 2009; Grossberg, 2009; Rao & Ballard, 1999; Serences, 2008; Summerfield & Egner, 2009). Predictive coding is an influential theory of visual object identification – it is not specific to faces. The theory argues, in part, that top-down processes (like expectation and motivation) have the capacity to distort perception. This theory is central to the current model, and we take this opportunity to highlight its essential points. Like classical theories of visual perception, predictive coding suggests that sensory information propagates through hierarchically organized stages of visual processing, from more concrete and specific to more abstract representations. But predictive coding contends that, at each stage of processing, this bottom-up signal is compared with an expectation generated at the level above. The discrepancy between the (top-down) expectation and the (bottom-up) observed signal iteratively modifies processing until the entire system converges on a representation. These feed-forward / feedback (observed / expectancy) loops are thought to occur simultaneously at every level of the hierarchically organized system. Perception thus shapes expectation, but top-down expectations about the nature of the stimulus also bias perceptual processes (including very early visual processing, Rauss, Schwartz, & Pourtois, 2011). Demonstrations of this top down bias have shown for example that, when participants learn to associate an auditory cue with a visual stimulus, presentation of the auditory cue (alone) can induce activity in primary visual areas – an indication that expectation shapes early visual processing (Den Ouden, Friston, Daw, McIntosh, & Stephan, 2009; McIntosh, Cabeza, & Lobaugh, 1998). And expectations based on the context in which an object appears can influence recognition (Bar & Aminoff, 2003).

Josh Correll 11/5/2015 10:53 AM
Comment [4]: Tor's reference to sequences of visual stimuli… Sharma?

b. Reciprocal processing

In fairness, experimental psychologists have argued for more than half a century that expectation guides perception. Bruner's (1957) work on perceptual readiness emphasized the idea that what we expect to see and what we want to see can influence what we do see. And this idea is alive and well in social psychology today (Balcetis, Dunning, & Granot, 2012; Correll, Wittenbrink, Crawford, & Sadler, 2015). In its simplest sense, predictive coding offers a neural process to explain these top-down effects. But predictive coding enables a more nuanced and much more interesting phenomenon: reciprocal processing. When perceivers are exposed to a novel face, the visual system quickly generates a coarse representation of the stimulus (this is largely a bottom-up process). This representation may then be compared with general expectations about what faces "normally" look like. Predictive coding theoretically allows the result of that comparison to engender motives and expectations (top-down processes) that bias perception (Bar, 2003).

It is interesting to note that, beyond the "core" network of face-selective regions in the brain (described above), face perception implicates a plethora of subcortical and cortical circuits, including the amygdala and the orbitofrontal and prefrontal cortices. The amygdala, which has been shown to respond to biologically relevant or arousing stimuli (Adolphs, 2010), reliably responds to emotionally expressive faces and, in some cases, to the faces of racial outgroup members (Cunningham et al., 2004, Hart, Whalen, Shin, McInerney, Fischer, & Rauch, 2000; Wheeler & Fiske, 2005; Vuilleumier & Huang, 2009). The orbitofrontal cortex and dorsomedial prefrontal cortex also respond to faces. These areas are thought to be involved in evaluation and the formation of an integrated social representation. The orbitofrontal cortex, in particular, may be involved in accessing relevant information from memory and generating predictions.

Activity in these regions can be triggered surprisingly quickly, leading researchers to posit a "fast pathway" that rapidly projects visual information from early visual areas in the occipital cortex to these more anterior regions (Bar, 2003; Johnson, 2005; Pessoa & Adolphs, 2010; Pourtois, Schettino, & Vuilleumier, 2013). Though fast, this pathway is thought to provide relatively impoverished, coarse representations (primarily low spatial frequency information, see Figure 2; Bar, 2003). Accordingly, the amygdala responds to faces very rapidly (within 120 ms, Streit, Dammers, Simsek-Kraues, Brinkmeyer, Wölwer, & Ioannides, 2003) and does so even when impoverished (subliminal) presentation precludes elaborate visual processing (Whalen et al., 2004; Pessoa, 2005; LaBar & Cabeza, 2006).

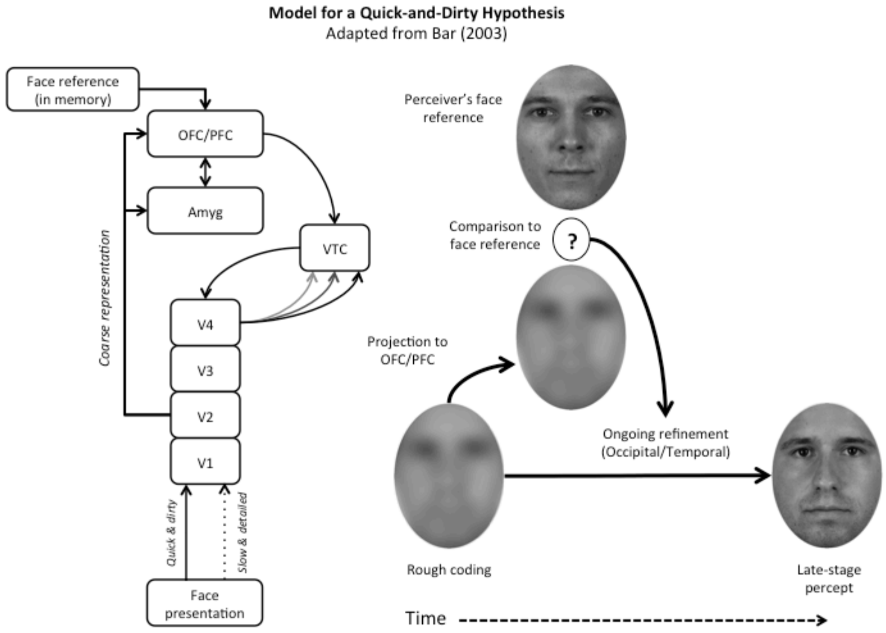
Model for a Quick-and-Dirty Hypothesis
Adapted from Bar (2003)

Figure 2. Top-down influences on perception, such that coarse representation of a face stimulus (rapidly projected from early visual processing and compared with exemplars in memory) allows the perceiver to generate a tentative hypothesis that guides ongoing, refined visual processing.

Combined with predictive coding, a quick-and-dirty route for visual processing could play a critical role in visual perception. Rapid projection of low-resolution information to regions like the amydgala or orbitofrontal cortex may allow the perceiver to generate a tentative guess about the nature of the stimulus, based in part on a comparison to relevant memories (Bar, 2003, 2004; Kveraga, Boshyan, & Bar, 2007). This rough hypothesis about the stimulus may then be projected back to regions involved in more rudimentary analysis, where fine-grained visual information is still being processed. The critical point is this: *a hypothesis that is derived in a bottom-up fashion from a quick-and-dirty representation of a particular stimulus may actively constrain on-going visual processing of that very same stimulus in a top-down fashion* (Johnson, 2005; Pourtois, Schettino, & Vuilleumier, 2013; Schyns & Oliva, 1994). In this manner, predictive coding allows for reciprocal influences, both bottom-up (stimulus-driven) and top-down (hypothesis-driven), in the visual processing of a given face.

Summary

Presentation of a face stimulus generates a rough perceptual representation, which may be projected to anterior regions of the brain (orbitofrontal and prefrontal cortices) where it can be compared to memory-based expectations (the face reference).[14] The result of this comparison process may constrain visual processing of the original stimulus in a top-down fashion (see Figure 2). To the extent that the initial, coarse percept falls close to the face reference (within some latitude of acceptance), it may induce an expectation that the face is a relevant member of the ingroup, and thus amplify configural, holistic processing and individuation ("who is this?"). To the extent that the rough percept falls far from the perceiver's expectation, engendering a sense that the faces is foreign, it may amplify attention to the discrepant stimulus as well as feature-based, categorical processing ("what kind of person is this?").

7. Perceptual enrichment, expectancy & reciprocal (PEER) processing model

We now present an integrative model of face processing (Figure 3), designed to explain documented phenomena in the domain of race and face processing. In particular, the model seeks to explain preferential individuation of SR faces, enhanced classification of SR faces as legitimate faces, preferential attention to CR faces, and enhanced categorization of CR faces according to social category.

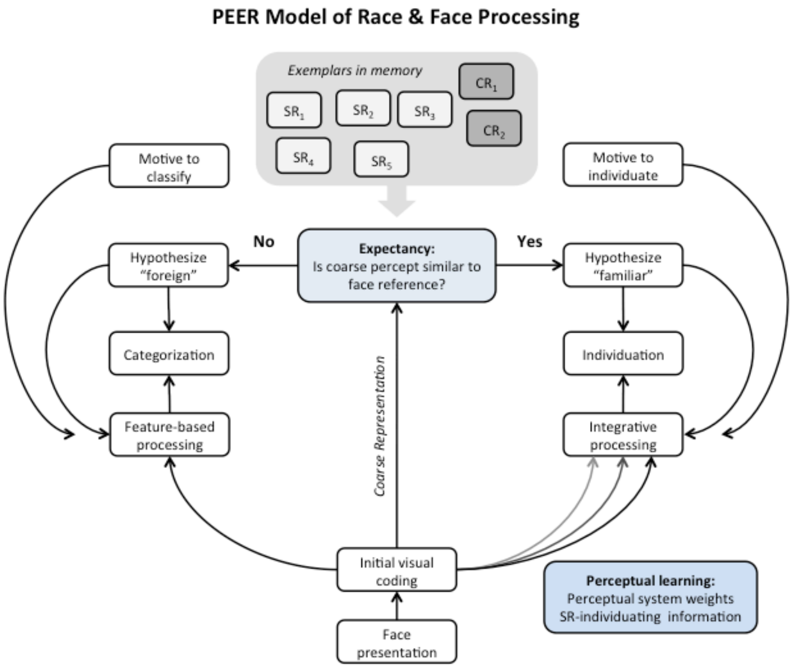

Figure 3. The perceptual enrichment, expectancy & reciprocal processing (PEER) model of race and face processing.

Given some minimum level of attention, presentation of a face should trigger a host of perceptual operations that propagate from early to later visual areas as visual information is gradually parsed and integrated to form an abstract representation (Van Essen & Maunsell, 1983). During this process, some physical dimensions are weighted more heavily, others less heavily, as a function of perceptual learning. Perceivers should rely more on dimensions of variation that have proved useful or diagnostic in the past (Caldara & Abdi, 2006; see Tanaka & Curran, 2001, for similar effects with non-face objects). So, although perceptual processes may be sensitive to a tremendous variety of features and configurations (all processed to some degree), perceptual learning should differentially weight the information available for subsequent processing. If perception is tuned by racially segregated experience, perception of SR faces should emphasize physical cues that correspond to SR identity-diagnostic information. Attention to the same physical cues in CR faces may be less helpful because those faces vary more meaningfully on other dimensions. In addition, whatever perceptual information is extracted may be more completely or effectively integrated into a unified percept for SR faces. The core prediction, here, is that the *percept, itself,* will provide a richer source of individuating information for SR faces, and a poorer source for CR faces.

Concurrently, during early stages of perception, coarse visual information is projected to anterior regions in the brain, allowing the perceiver to rapidly generate an expectation about the nature of the stimulus (Bar, 2003). This coarse representation is compared to the perceiver's subjective understanding of a normative face. The result of this comparison engenders a hypothesis about the nature of the current stimulus. Because SR faces typically fall close to the face reference (within the latitude of acceptance), they prompt a hypothesis that the face is normal or even familiar. Because CR faces are more likely to deviate from the reference, they evoke a hypothesis that the face is foreign. In a top-down fashion, the resulting hypothesis then modulates ongoing visual processing through projections back to the ventrotemporal cortex (and other regions engaged in early visual processing) (see Schettino, Loeys, Delplanque, & Pourtois, 2011; Summerfield, Egner, Greene, Koechlin, Mangels, & Hirsch, 2006).

Top-down influences can and should include influences other than comparison with the face reference. Factors such as context, motivation, and task instructions may similarly alter perceptual operations that are gradually unfolding in the occipital and temporal cortices. In an experiment, a perceiver may be explicitly instructed to individuate or classify the face. At a party, an introduction from a friend may evoke different motives than squeezing by someone in the hall. Each of these factors may bias visual processing through the same predictive coding mechanisms.

It is important to note that, according to this framework, top-down motives and hypotheses can influence bottom-up processes, but they do not simply override long-standing expertise-based changes in perceptual learning. Even when a perceiver is motivated to identify an unfamiliar CR face, perceptual learning (which overweights SR-diagnostic features) should make individuation difficult. If the perceptual system fails to emphasize features that meaningfully differentiate members of CR faces, the perceiver's perceptual representation of that face may contain less identity-diagnostic information. Even when the perceiver is highly motivated or instructed to individuate that face, an impoverished percept may make the task difficult and effortful.

a. Explaining effects of race on face processing

CR Recognition Deficit. The model accounts for impaired CR recognition in two ways. Operating in a more bottom-up fashion, perceptual enrichment should enhance the representation of SR faces relative to CR faces. In addition, operating in a more top-down fashion, the degree of correspondence between the stimulus and the face reference should alter processing goals. For SR faces, an enriched percept should make the process of individuation easier, and a hypothesis that the face is normative should enhance motivation to individuate the face. By contrast, for CR faces, an impoverished percept and a sense that the face deviates from the norm may constrain the perceiver's ability and motivation to individuate the face (and may even evoke a motivation to classify it).

In this context it is interesting to consider evidence that, (a) even for SR faces, categorizing a face as an outgroup member impairs recognition and holistic processing (e.g., Hehman, Mania, & Gaertner, 2010; Bernstein, Young, & Hugenberg, 2007; Hugenberg & Corneille, 2009), and (b) instructions to try harder can improve CR recognition. With respect to the first point, we note that even if rich perceptual information is salient in SR faces, manipulations that reduce the perceiver's motivation to individuate may alter top-down processing, attenuating holistic and configural processing. With respect to the second point, perceptual tuning may leave the perceiver with relatively impoverished information about a CR face, but manipulations that induce individuation goals should enhance efforts at holistic and configural processing. Given an impoverished percept, the task of individuation may be more difficult for CR faces, but sufficient effort and cognitive resources may minimize the CR recognition deficit. For example, Senholzi and Ito (2012) found that, when White participants were *explicitly* *instructed to individuate faces*, they showed a more pronounced N170 to Black (rather than White) targets – a reversal of the pattern often observed during normal face viewing, in which N170's are larger for SR faces. The authors interpreted this difference as evidence that more cognitive resources were required for the individuation of CR faces. (We might also predict that instructions to classify an SR face would attenuate holistic and configural processing; cf. Hugenberg & Corneille, 2009).

Classification of a stimulus as a face. As described above, Valentine (1991) observed that participants were faster to identify a given stimulus as a face if it belonged to the racial ingroup. The time required to classify a stimulus as a face presumably reflects the degree to which that stimulus deviates from the perceiver's abstract representation of a face. To the extent that individuals have more experience with SR faces (relative to CR faces) and more SR exemplars in memory, the model clearly suggests that the general face reference should be more similar to SR faces, leading to faster recognition that an SR face is, in fact, a face.

Preferential attention to CR faces. Allocation of attention is biased toward CR faces, and these biases emerge at relatively early stages of processing (Ito & Urland, 2003). The model accounts for these effects primarily as a consequence of rapid processing of coarse visual information. Stimuli that deviate from the face reference should evoke a hypothesis that the stimulus is foreign and, so, enhance attention to category (Johnston, Hawley, Plewe, Elliott, & DeWitt, 1990). In a sense, this process involves the inverse of the face-classification process described above. Classification of a stimulus as a proper face should be difficult to the extent that it deviates from what is viewed as typical or normative. The same process should amplify attention.

Cross-race classification advantage. The model also suggests that the cross-race classification advantage emerges because a coarse representation of a CR face deviates from the perceiver's representation of a normal face (the face reference). This mismatch may either promote categorical, feature-based processing or simply fail to induce individuated processing. In either case, it should facilitate categorization (Laeng, Zarrinpar, & Kosslyn, 2003). For SR faces, by contrast, a match to the face reference may promote individuated processing (and potentially impair categorical processing).

b. Relationships with existing models of race and face processing

The Ingroup/Outgroup Model. The PEER model owes a tremendous debt to the work of Sporer (2001) whose Ingroup/Outgroup Model describes how perceivers differentially respond to SR and CR faces. Sporer's model posits that perceivers process faces in an individuated fashion by default, attending to information about identity and (for SR faces) ignoring category-specifying cues. When presented with a CR face, however, Sporer suggests that the default process is interrupted by detection of an "outgroup cue," which enhances attention to the category, impairing holistic/configural processing and leading to cognitive disregard. Though Sporer (like Levin, 2000) does not clearly specify the nature of this outgroup cue, his model thus accounts for the possibility that detection of a CR face can both quantitatively reduce the extent of individuation and qualitatively alter the nature of processing.

The Categorization-Individuation Model. Hugenberg and his colleagues (2010; Young, Hugenberg, Bernstein, & Sacco, 2012) proposed the Categorization-Individuation Model (CIM), which suggests that face processing is affected by the perceiver's tendency to socially categorize faces, their motivation to individuate a particular face, and their experience individuating SR faces. This model offers a set of four predictions. First, in line with the idea of categorical perception, it suggests that categories lead to perceptual assimilation. Second and third, it suggests that motivation and individuation experience each improve face memory. Finally, it suggests that the benefits of experience depend on motivation. Although the CIM posits that both motivation and experience can improve memory for faces, it does not clearly specify the relationships between the two factors, nor does it articulate the cognitive or neural processes underlying their effects.

The model proposed here differs from this previous work in several ways. It integrates and extend previous work by offering an account of the effects of expertise (and by association, of race) on face perception that (a) provides a neuroscientifically plausible account of psychological processes, (b) explains the majority of existing data regarding a range of phenomena (e.g., biases in attention, and categorization, as well as the CR recognition deficit), (c) articulates how different influences, such as motivation and expertise, should interact, and (d) generates new and testable hypotheses. The present model also offers a potential solution to the puzzle of the elusive "race-specifying feature" (Levin, 2000) or "outgroup cue" (Sporer, 2001).

c. Some predictions of the model

Effects of expertise on perception, attention & classification. First, and most obviously, the model predicts that more extensive experience individuating CR faces should reduce the CR recognition deficit by both (a) tuning (or retuning) the perceptual system in ways that enrich the perceptual representation of CR faces and (b) by altering the mental representation of a typical face. These processes should increase both the ability and motivation to engage in holistic, individuated processing. Childhood contact does, indeed, seem to covary with holistic/configural processing of CR faces (Hancock & Rhodes, 2008; Hayward, Rhodes, & Schwaninger, 2008), and we have recently shown that it is also associated with a relative increase in right-lateralized (presumably holistic) processing for the outgroup (Davis et al., 2015). The model also suggests that CR experience should be negatively associated with attention to racial category information (Dickter et al., 2015) and positively associated with face-classification speed for CR faces. There is little work directly testing these relationships, but we view them as interesting avenues for future research.

The role of coarse visual information. Second, for a typical perceiver with low levels of CR contact, the model suggests that many well-documented effects of race may be mediated by quick-and-dirty processing of racial information. More specifically, it predicts that a coarse representation may *qualitatively* alter the way perceivers process faces. Cues that quickly convey outgroup status may lead to increases in feature-based processing; cues that quickly convey ingroup status should induce more holistic processing (Goldinger et al, 2009). If differences in the holistic versus feature-based nature of face processing underlie certain effects of race (e.g., difficulty in identifying CR faces as faces, and the CR recognition deficit), the model thus suggests that quick-and-dirty information should be sufficient to induce them. We have already obtained some evidence supporting the idea that coarse (low spatial frequency) visual information is sufficient to classify faces by race and to induce the cross-race classification advantage (Correll, Tobin, & Hudson, 2015). Future studies will explore the idea that cues to outgroup status can also evoke preferential attention and impair recognition. It is particularly interesting to consider the possibility that these quick-and-dirty signals may initiate differences in face processing that cascade downstream to ultimately influence associations and inferences, for example, stereotypes.

Expertise & ease of individuation. Third, considering CR recognition, the model offers a potentially valuable distinction between the effects of CR contact and the effects of motivation. Though both variables may improve recognition accuracy (cf. Hugenberg, Young, Bernstein, & Sacco, 2010), the model suggests that the *processes* by which they do so should differ. Improvements in CR recognition that derive from individuated contact should be characterized by changes in expert-like perception (perceptual learning and holistic processing). They should be routinized and efficient (Richler, Wong, Gauthier, 2011). As a consequence, we expect them to be robust in the face of manipulations that deprive perceivers of the resources to process a CR face. Manipulations that increase cognitive load or decrease the duration of stimulus presentation should therefore have relatively minimal impact on perceivers who have extensive CR contact. CR contact may also qualitatively alter the nature of CR face processing, leading to more extensive holistic processing operations that usually typify SR processing (e.g., eye scan paths that move quickly across multiple features rather than fixating for long periods of time on a few features, Goldinger et al, 2009). In contrast, for participants with minimal CR contact, perceptual representation of a CR face should be relatively poor. Experimental manipulations that induce a *motivation* to recognize CR faces may thus lead to effective-but-inefficient processing, characterized by brute-force implementation of non-optimal processing strategies. This possibility would suggest that motivated improvements in performance will be compromised by cognitive load. Alternatively, motivation (without expertise) may prompt the perceiver to shift strategies, seeking to "individuate" CR faces by means of distinctive features rather than by the kind of configural or holistic processing that typifies SR face identification.

Effects reflect differential contact (not race). Fourth and perhaps most importantly, the model suggests that many of the effects described in this paper are not effects of *race* at all. Apparent effects of race on face processing may, in truth, represent the consequences of contact and familiarity (individuated exposure), which are typically confounded with race. This is a deceptively simple idea with profound implications. It suggests that race-like effects may emerge for any set of faces that differ morphologically from those with which the perceiver is familiar. An example of differences in familiarity (unrelated to race) is the own age bias in face recognition: perceivers show better recognition of their peers than of people of different age groups (e.g., Wiese, Schweinberger, & Hansen, 2008). But we also suggest that a White individual raised in Sweden should respond to a White (and thus SR) face from Spain as unfamiliar; a Black individual in Botswana may respond to a Black face from Ivory Coast as unfamiliar; even within the same country, a Japanese person from Okinawa may respond to a Japanese face from Hokkaido as unfamiliar. Structurally unfamiliar faces, even faces belonging to a *racial ingroup,* may thus induce the kinds of feature-based processing, enhanced attention, advantages in categorization, and impaired recognition that would typically characterize the processing of a CR face. A related implication is that increased contact with a given racial outgroup should have consequences for the visual processing of other racial outgroups to the extent that the two outgroups are morphologically similar. It might be instructive to explore the effects of individuated contact with Native Americans on perceptions of Asian faces because, in the course of human prehistory, these two populations are thought to have separated relatively recently (Fagundes et al., 2008). A third implication, at least in the US, involves the integration/segregation of public schools. Court-ordered integration programs have disappeared. In fact, in a dramatic reversal, efforts to increase racial diversity in schools that were undertaken voluntarily by several states and municipalities have been dismantled by the Supreme Court (which once mandated integration). To the extent that CR contact alters the way individuals perceive racial outgroups, de facto racial segregation in public schools may have important social consequences by reifying the psychological impact of race.

8. Conclusion

Even when behavior appears universal or innate, its emergence can depend on experience. In fact, "universal" behavior may only appear universal because the experience, itself, is so widespread. For example, it may seem predetermined by biology that chickens eat mealworms or that human infants crawl by moving their arms and legs in a diagonal pattern (with the left leg and right arm going forward at the same time). These behaviors emerge in virtually every member of the respective species, and an observer might be tempted to conclude that they are innate. But that universality is misleading – these behaviors are not preprogrammed. Oddly enough, if a chick is prevented from seeing its own toes by means of a cloth foot cover for two days after it hatches, it will not eat mealworms as an adult (Wallman, 1979). And human babies do not exhibit diagonal coordination when they crawl on their bellies. When they develop the strength required to lift their torsos off the ground (and only then), they *learn* to employ diagonal movement as a way to maintain balance (Freedland & Bertenthal, 1994; see Gottlieb, 1991). Of course, most chicks do not wear foot covers, so they have the requisite experience of seeing their toes (and they eat mealworms). Babies eventually lift their bodies when they crawl, so they adopt a common solution to the problem jointly posed by gravity and the physical structure of the human body (and they move their limbs in a diagonal pattern). But in both cases, *experience plays a crucial role*. Species-typical behaviors can emerge in response to species-typical experience. This universal but experience-dependent (or experience-expectant) behavior is not limited to basic functions like locomotion and feeding. Experience can also be crucial for complex, social behaviors like the human capacity to infer intention (Sommerville, Woodward, & Needham, 2005).

Like other experience-dependent behaviors, the current paper argues that the widespread effects of race on social cognition derive from a species-typical human experience, racial segregation. We interact primarily with other members of the racial ingroup, and the facial features of our ingroup differ, physically, from those of outgroups. We argue that cognitive and perceptual mechanisms (which have no inherent sensitivity to race) are sculpted by that segregated experience. Race structures the world around us, and our minds absorb and reflect that structure, imbuing facial morphology with profound psychological significance, giving the (false) impression that race is and must be a fundamental dimension of social perception.

Footnotes

[1] Unlike explanations of intergroup bias based on conceptual or symbolic representations of the ingroup and outgroup (e.g., Cosmides et al., 2003), we are postulating that this is a

[2] There are certainly other, profound effects of contact. People who report higher levels of CR contact tend to have more positive attitudes toward racial outgroups (Hewstone & Brown, 1986; Pettigrew & Tropp, 2006). But this paper is not directly concerned with the effects of contact on attitudes. Rather, we are interested in the way that individuated contact affects the *visual processing* of CR faces.

[3] Perceptual tuning to the racial ingroup during the first year of life does not seem to be accompanied by evaluative preference for that ingroup. Nine-month-olds show impoverished individuation of racial outgroup members, but, at 10 months and 2.5 years, they are willing to interact with them. Somewhere between 2.5 and 5 years, racial bias begins to emerge (Kinzler & Spelke, 2011).

[4] Although deficits with CR faces emerge in the first year of life, children remain flexible. Asian children adopted by White parents living in (predominantly White) Western Europe show reduced deficits in processing White faces (de Heering, de Liedekerke, Deboni & Rossion, 2010; Sangrigoli, Pallier, Argenti, Ventureyra, & De Schonen, 2005). Moreover, the age at which they were adopted (ranging from 6 years to 14 years) was unrelated to performance with White faces, suggesting that effects of CR contact are not limited to a critical window during infancy. It is interesting to compare this extended period of flexibility with the long-term deficits displayed by infants who (because of cataracts) were deprived of any face stimuli (Le Grand, Mondloch, Maurer, & Brent,

2001). Experience with at least some faces during the first few months of life seems to provide critical visual input, allowing the infant to develop neural systems for face processing, including configural and holistic processing (Johnson, 2005). Although CR faces may differ in terms of second-order configuration and features, individuated CR exposure (as late as age 10) seems to allow a child to translate existing (SR) face processing skills to CR faces. By contrast, infants deprived of exposure to any faces during the first few months of life may never develop systems for face processing in the first place – a deficit that seemingly cannot be overcome through subsequent exposure.

[5] Exposure during adulthood may have weaker effects (Meissner & Brigham, 2001; MacLin et al., 2004). Although intensive perceptual discrimination training can reduce deficits in recognition performance (Lebrecht et al, 2009; McGugin et al., 2011), it does not seem to yield equivalent processing of SR and CR faces on more subtle measures of processing, such as the N170 (Tanaka & Pierce, 2009).

[6] Valentine's model offers some insight into distinctions between experience and expertise. Greater *experience* with SR (rather than CR) faces should populate the face space with more SR exemplars and fewer CR exemplars. Differential *expertise* with SR faces should promote greater differentiation between SR exemplars, and tighter clustering of CR faces.

[7] Scientifically, the concept of race is problematic (Glasgow, 2003; Rosenberg, Pritchard, Weber, Cann, Kidd, Zhivotovsky, & Feldman, 2002; Rothbart & Taylor, 1992; Smedley & Smedley, 2005). Though rarely defined explicitly in social psychology, race is typically conceptualized in terms of a few major divisions of human kind, associated with

ancestry from geographically distinct regions of the Earth (e.g., Europe, Africa, Asia), and corresponding phenotypes for skin tone and facial morphology. But the scientific value of the term, race, has been challenged. In particular, authors have disputed the idea that race (a) offers a scientifically meaningful way to divide people into discrete groups and (b) provides a biological explanation for differences in ability or personality (Smedley & Smedley, 2005). We do not argue that race is "real" in either sense. The present argument simply involves the idea that facial morphology varies as a function of ancestral origin and genotype, and that this variation corresponds (if imperfectly) to the social construct of race, which segregates social interaction.

[8] However, morphology may not correspond perfectly to the migratory or even the genetic distance between groups. Genetic changes may arise for multiple reasons. Some changes in morphology may derive from genetic changes that are evolutionarily neutral (i.e., irrelevant to reproductive fitness). For example, *genetic drift* refers to random fluctuations in the genotype due to sampling during reproduction. These neutral mutations promote graded changes in morphology that correspond closely to other changes in the genotype. Accordingly, they should correspond to the genetic distance between populations (Betti et al., 2009). Other genetic changes reflect functional adaptation to the environment. They are not purely random because natural selection favors phenotypic changes that help the individual address particular environmental challenges (like diet or the intensity of the sun). Natural selection may therefore promote morphological similarities between genetically/geographically distant subpopulations if those subpopulations inhabit similar environments. For example, although the Inuit and

Siberian populations come from relatively distant genetic clusters, Smith (2011; see also Nicholson & Harvati, 2006) identified similarities in their basicranial morphology that seem to reflect adaptations to a partially frozen diet. A combination of evolutionarily neutral processes (which promote gradual differentiation as a function of migratory/genetic distance) and natural selection (which promotes adaptations to environmental challenges) yields a complex set of influences that blur distinctions based on geography.

[9] Of course, race and ethnicity are routinely freighted with cultural associations. Blacks and Latinos may be associated with threat, Asians with intelligence. Some groups may be viewed positively, others negatively. We acknowledge the profound impact that stereotypes and prejudices may have on all sorts of psychological operations, but our model addresses a different question. It focuses on consequences of the physical structure of the face.

[10] Segregation can persist even when a group is officially integrated. In the last half of the 20th century, a number of school districts in the US were ordered to integrate their student populations. Though these moves were intended (in part) to promote interracial contact, in an analysis of one nominally integrated middle school, Schofield and Sagar (1977) found that students segregated themselves. At lunch, for example, students opted to sit with SR classmates (and avoided CR classmates) much more frequently than would be expected by chance. Even in a formally integrated context, then, social interaction was biased toward people with similar phenotypes.

[11] We want to acknowledge that we are making an assumption here. We assume that racial groups differ in the physical dimensions that are most useful for individuation (e.g., the features that best differentiate Black faces are not the same as the features that best differentiate Asians). Though we know of very little work that directly examines this question, the relevant work we have found supports our position (Caldara & Abdi, 2006). We are currently testing this assumption (Correll, Ma, & Kenny, 2016).

[12] This argument is based on the idea that most perceivers do not practice individuating CR faces. It is also possible that they *do practice* categorizing or classifying CR faces, potentially engaging perceptual learning in a way that increases the salience of category-specifying features (cf. Levin, 2000).

[13] Contrary to our argument about right lateralization, however, the race-based differences they report are stronger in the left hemisphere.

[14] It is also possible that these expectations can be influenced by the situation (e.g., the environment, other recent encounters, or experimental instructions).

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