# Understanding evaluation of faces on social dimensions

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**People reliably and automatically make personality inferences from facial appearance despite little evidence for their accuracy. Although such inferences are highly inter-correlated, research has traditionally focused on studying specific traits such as trustworthiness. We advocate an alternative, data-driven approach to identify and model the structure of face evaluation. Initial findings indicate that specific trait inferences can be represented within a 2D space defined by valence/trustworthiness and power/dominance evaluation of faces. Inferences along these dimensions are based on similarity to expressions signaling approach or avoidance behavior and features signaling physical strength, respectively, indicating that trait inferences from faces originate in functionally adaptive mechanisms. We conclude with a discussion of the potential role of the amygdala in face evaluation.**

## Introduction

The human face is a perennial source of fascination as a window to one's character [1]. Indeed, people routinely make trait inferences (e.g. aggressiveness) from faces, despite mixed evidence for the accuracy of these inferences (Box 1). As little as 100 ms exposure to unfamiliar faces provides sufficient information for trait inferences [2,3] and evolutionarily important inferences such as threat can be made even after shorter exposures [4]. These inferences predict important social outcomes ranging from electoral success to criminal sentencing decisions [5–9]. For example, inferences of competence based solely on facial appearance predict U.S. Senatorial and Gubernatorial elections [3,7] and inferences of dominance predict military rank attainment [10].

The traditional approach to studying trait inferences from facial appearance has been to focus on specific trait dimensions (Box 2). For example, among trait inferences, inferences of trustworthiness [11] have received extensive research attention in both behavioral [12–15] and functional magnetic resonance imaging (fMRI) studies [16–19]. However, focusing on a single trait dimension is problematic because trait judgments from faces are highly correlated with each other [20]. That is, for any set of faces, there are multiple social dimensions that co-vary with each other and, thus, several alternative explanations of observed empirical relationships between a trait judgment and a behavior or brain activation. For example, two trait judgments – how caring and how attractive a person is – accounted for 84% of the variance of trustworthiness judgments that predicted the amygdala activation to faces in an fMRI study of implicit face evaluation [17]. Without independent evidence for the primacy of one trait inference over another, it is equally plausible to argue that 'caring' inferences and attractiveness, rather than trustworthiness, drive the response of the amygdala to faces. Statistically controlling for such variables is almost impossible given the large proportion of shared variance. Although it is possible to experimentally unconfound variations of faces on social dimensions, it is not at all clear what dimensions one should choose given their exceedingly large number. (In English, there are at least 4000 adjectives that describe interpersonal relationships [21].)

Instead of focusing on single trait dimensions, we advocate an alternative, data-driven approach with the objectives of finding the structure and perceptual basis of judgments from emotionally neutral faces. This approach is better suited than traditional approaches to address two of the fundamental questions of the study of social judgments from faces: what do these judgments really measure and what is their functional basis?

## The structure of face evaluation

To identify dimensions used to spontaneously characterize faces, we selected the most frequently used trait dimensions from unconstrained person descriptions of emotionally neutral faces [20]. The faces were then rated along these dimensions by separate groups of participants. For each face, the mean ratings on the dimensions were submitted to a principal components analysis (PCA), a technique that reduces data dimensionality (Box 3). The first two principal components (PCs) accounted for more than 80% of the variance of the judgments. The first PC, which accounted for more than 60% of the variance, could be interpreted as valence given its strong positive relationship with positive trait judgments (e.g. trustworthiness) and strong negative relationship with negative trait judgments (e.g. aggressiveness). The second PC could be interpreted as power or dominance given its strong positive relationship with judgments of dominance, confidence and aggressiveness.

This solution was quite robust as shown by a PCA of trait judgments of computer-generated faces. The solutions from the two separate sets of faces – one natural and the other computer generated – were remarkably similar (Figure 1), even though they were estimated from only partially overlapping sets of trait judgments. For example, in both solutions, judgments of trustworthiness and dom-

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**Box 1. Accuracy of social judgments from faces**

Whether facial appearance yields accurate information about personality, as posited by the 'kernel of truth' hypothesis, remains an interesting and controversial issue. Several studies have reported moderate correlations between trait inferences from faces as rated by others and self-reports of approachability, warmth, power and extraversion [38–40], but null results have been reported for agreeableness and conscientiousness [41].

All of these studies measured personality with self-reports. Another approach is to rely on observational and behavioral measures. Using this approach, no significant correlation was found between the facial appearance of honesty and clinically assessed honesty [42]. Another study measured behavior and found that participants whose faces were rated as dishonest were more likely to participate in experiments involving deception of other participants than participants whose faces were rated as honest [43], although the correlation was weak (.20).

One possible mechanism for accuracy is the self-fulfilling prophecy [1]. It is possible that people who are treated as if they have a certain personality trait because of their facial appearance will actually develop that trait in response to interactions with others. However, it is also possible that the self-defeating prophecy might cause the reverse effect. People who are treated as if they have a particular trait might compensate by developing the opposite trait. Support for this latter hypothesis has been found in adolescent baby-faced boys, who show greater academic achievement, thus counteracting the stereotype of baby-faced people as intellectually weak (Box 2). Low socioeconomic status baby-faced boys are also more likely to be delinquent, counteracting the stereotype of baby-faced people as submissive and benign [44].

In summary, the evidence for the 'kernel of truth' hypothesis is mixed. There seems to be a consistent relationship between measures of extroversion and facial appearance across studies, but not for other measures of personality. Evidence for accuracy in judgments of honesty and baby-faced related stereotypes varies as a function of paradigm and participant population. In most cases, it would be interesting to investigate why judgments of some traits are accurate, whereas others are not. Similarly, it could be that judgments would accurately predict behaviors in some situations but not others. Methodologically, definitive studies on the accuracy of judgments require representative sampling of targets from a full range of faces and personalities.

**Box 2. Influence of baby-faced appearance on social judgments**

The science of 'cute' began in the middle of the twentieth century when Konrad Lorenz [45] posited that infantile features automatically evoke a nurturing response in adult perceivers. The efficacy of traits such as large eyes, large head and small jaw is so prepotent, he argued, that non-human animals possessing them enjoy increased human affection. That is, we are so automatically moved to a nurturing state by these physical features that we respond to them even when displayed by non-human animals. Stephen Jay Gould [46] famously summarized this idea in an essay in which he described the 50-year morphological evolution of Mickey Mouse from adult-faced troublemaker to baby-faced icon. Knowingly or otherwise, Disney animators have increasingly exploited Lorenz's idea by, among other changes, increasing the size of Mickey's eyes and head.

More recently, psychologists have applied this notion to the social consequences for adults who retain juvenile facial features. The majority of this work has been done by Leslie Zebrowitz and her colleagues [1,6], who have demonstrated that 'baby faced' adults are assumed to be warmer, more honest, more naïve and weaker than their mature-faced peers. Moreover, they have shown that these impressions can have potentially profound consequences. For instance, both criminal and civil judicial verdicts can be predicted by whether or not the defendant is baby faced [47], despite mixed evidence regarding how well these trait impressions predict the actual behavior of an individual (Box 1).

Zebrowitz and her colleagues [29,48] have argued that the automatic response to facial features in babies is overgeneralized to adults who share them, resulting in appearance driven trait impressions. Consistent with this hypothesis, they have shown that faces that are ascribed child-like traits are more likely to be confused with baby faces by a neural network model trained to distinguish baby faces from adult faces [48]. The overgeneralization hypothesis posits that these appearance-driven impressions are adaptive, regardless of validity, to the extent that the cost of inaccurately inferring child-like traits from baby-faced adults is less than the cost of responding inappropriately to the needs of infants.

inance were closest in space to the first and second PC, respectively (Figure 1). This was the case even when the PCs were estimated from a set of judgments excluding trustworthiness and dominance [20].

Although the model was data-driven and built from judgments of faces, it converges with several dimensional models. Most strikingly, the meaning of the two components is very similar to the first two factors underlying evaluation of concepts, revealed fifty years ago by Osgood and his colleagues [22]. The face evaluation model is also similar to models of interpersonal perception [21,23] and intergroup perception [24]. For example, Wiggins and his colleagues [21,23] have shown that interpersonal relationships can be described along two orthogonal dimensions – affiliation and dominance – that seem to map onto the valence/trustworthiness and power/dominance dimensions of face evaluation.

## The perceptual basis of face evaluation

The 2D model described earlier served as a guiding framework for computer modeling of face variation on social

**Box 3. Principal components analysis**

Principal components analysis (PCA) is a widely used data reduction technique developed independently by Karl Pearson [49] and Harold Hotelling [50]. The primary goal of PCA is to reduce the dimensionality of a dataset containing a large number of correlated variables, while preserving as much of the variance of the original dataset as possible. The procedure transforms the original variables to a new set of variables called principle components (PCs), which are orthogonal to each other, and ordered by the amount of additional variance they explain in the original dataset. This allows the researcher to succinctly describe the data, often using only the first few PCs. An extension of this use is to replace correlated variables in regression problems afflicted by multicollinearity with orthogonal PCs.

PCA can add clarity to a large intractable dataset by reducing the number of variables to a few components. In addition to psychology, it is used in many other fields such as meteorology (summarizing pressure fields) and chemistry (predicting activity properties of as yet undeveloped compounds). As with all statistical techniques, there are caveats that should be considered carefully before applying PCA. For instance, the number of PCs to be used is not clear. The addition of each PC increases the amount of variance explained, but at the expense of a loss of parsimony. There is no prescriptive number that is agreed upon, although there are several guidelines for this problem [51]. One should also consider that the primary utility of PCA, discarding information, could also be a liability. It is possible that the answer to interesting scientific questions can be found in the variance unexplained by the PCs that account for most of the variance.

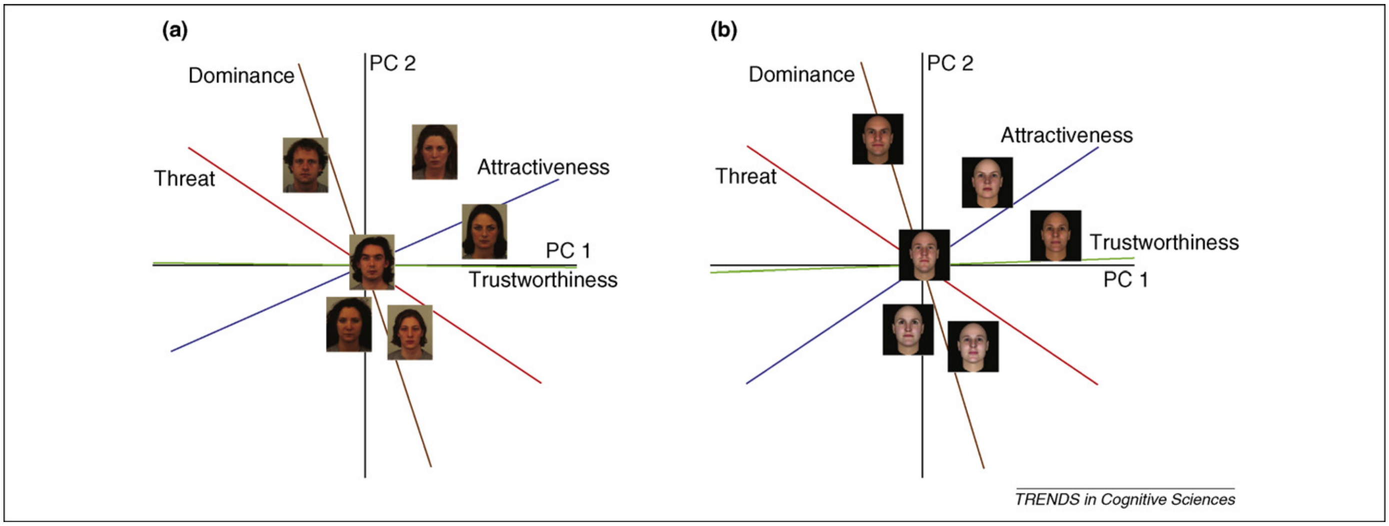


**Figure 1**. The structure of face evaluation. Plots of solutions of principal components analysis of trait judgments of **(a)** 66 natural faces and **(b)** 300 computer-generated faces. The first PC could be interpreted as valence/trustworthiness evaluation, and the second PC component could be interpreted as power/dominance evaluation [20]. The PCs are a weighted linear combination of trait judgments. The plots show the location of judgments of trustworthiness, dominance, threat and attractiveness within the 2D space of face evaluation. The smaller the angle between a trait dimension and a PC, the stronger their relationship. The plots also show natural and computer generated faces with similar location in the 2D space. The length of each line represents 6 SD units (+3/−3 SD relative to the origin).

**Box 4. Computer models of face representation**

Recent developments in computer graphics have allowed for the generation of realistic 2D and 3D faces that occupy positions in a multidimensional face space [52]. The computer modeling of social judgments described in this article used a derivative of a morphable model of 3D faces developed by Blanz and Vetter [25]. The original model was derived by first acquiring shape information from laser scans of a set of example faces. Faces were aligned and then represented as a set of vertices that define the face surface. A PCA was then performed on these vertex positions, resulting in a lower-dimensional face space that accounts for most of the face shape. In such models, new faces can be generated as linear combinations of the principal components (Figure 2b in the main text), while imposing certain constraints for allowable faces determined by the statistics of the original set of example faces.

Controllable face spaces allow for the generation of new stimuli that can be used to test psychological hypotheses that could not be easily tested with natural faces [20]. They also can serve as plausible and testable models of how faces are represented in the brain. For instance, how the brain represents facial identity can be investigated using caricatures and 'anti-faces' (i.e. the face vector multiplied by −1). Caricatures and anti-faces create a single dimension that runs through an 'average face'. Crucially, multiple dimensions can all share the same average face. Caricatures are perceived to retain the identity of the original face, and are easier to recognize [53,54], providing evidence that humans code information about faces relative to a norm at the center of face space [55], instead of matching to a set of stored exemplars. Psychological adaptation to anti-faces facilitates the identification of original faces more so than does adaptation to a separate face equally distant from the original face [56]. Consistent with this evidence in support of norm-based coding theories, electrophysiological recording from neurons in the anterior inferotemporal cortex of macaque monkeys, who were shown faces spanning multiple directions in face space, shows that the firing of many neurons increases monotonically with the distance from the average face [57].

dimensions. Given that trustworthiness and dominance judgments were closest in space to the two PCs, we modeled how faces vary on these dimensions using a data-driven statistical model of face representation (see Ref. [25], and Singular Inversions, 2005: http://www.facegen.com). First, we collected trustworthiness and dominance judgments of computer-generated faces. Second, based on these judgments, we built dimensions optimal for changing face trustworthiness and dominance in a 50-dimensional space representing face shape (see Box 4 and Figure 2).

The trustworthiness and dominance dimensions define a simple 2D space within which specific social judgments can be represented [20]. For example, threatening faces are perceived as both untrustworthy and dominant, and faces that vary on threat can be obtained by a linear combination of faces that vary on trustworthiness and dominance (Figure 2d).

Using computer models of face evaluation, it is possible to generate an unlimited number of faces and to manipulate face variations along a given dimension. Moreover, given that these dimensions are constructed to be optimal in representing specific face variations, it is possible to discover the features important for face evaluation on a specific dimension by exaggerating faces along this dimension [20]. That is, these models can be used to amplify the diagnostic signal in the face that is used for the specific judgment. For example, although faces that varied on trustworthiness were perceived as emotionally neutral within a 3 standard deviation (SD) range, they were perceived as emotionally expressive outside of this range. Whereas faces at the extreme negative end of the dimension seemed to express anger, faces at the extreme positive end seemed to express happiness (Figure 2d). Attributions of these emotions changed as a monotonic function of face trustworthiness [20]. Changes along the dominance dimension, which was orthogonalized to the trustworthiness dimension, were less sensitive to emotional cues but more sensitive to cues signaling physical strength. Whereas extremely submissive faces were perceived as feminine and baby faced (Box 2), extremely dominant faces were perceived as masculine and mature faced (Figure 2d).

This modeling approach could be combined with other data-driven techniques designed to reveal the diagnostic information used for specific judgments [26]. For example,

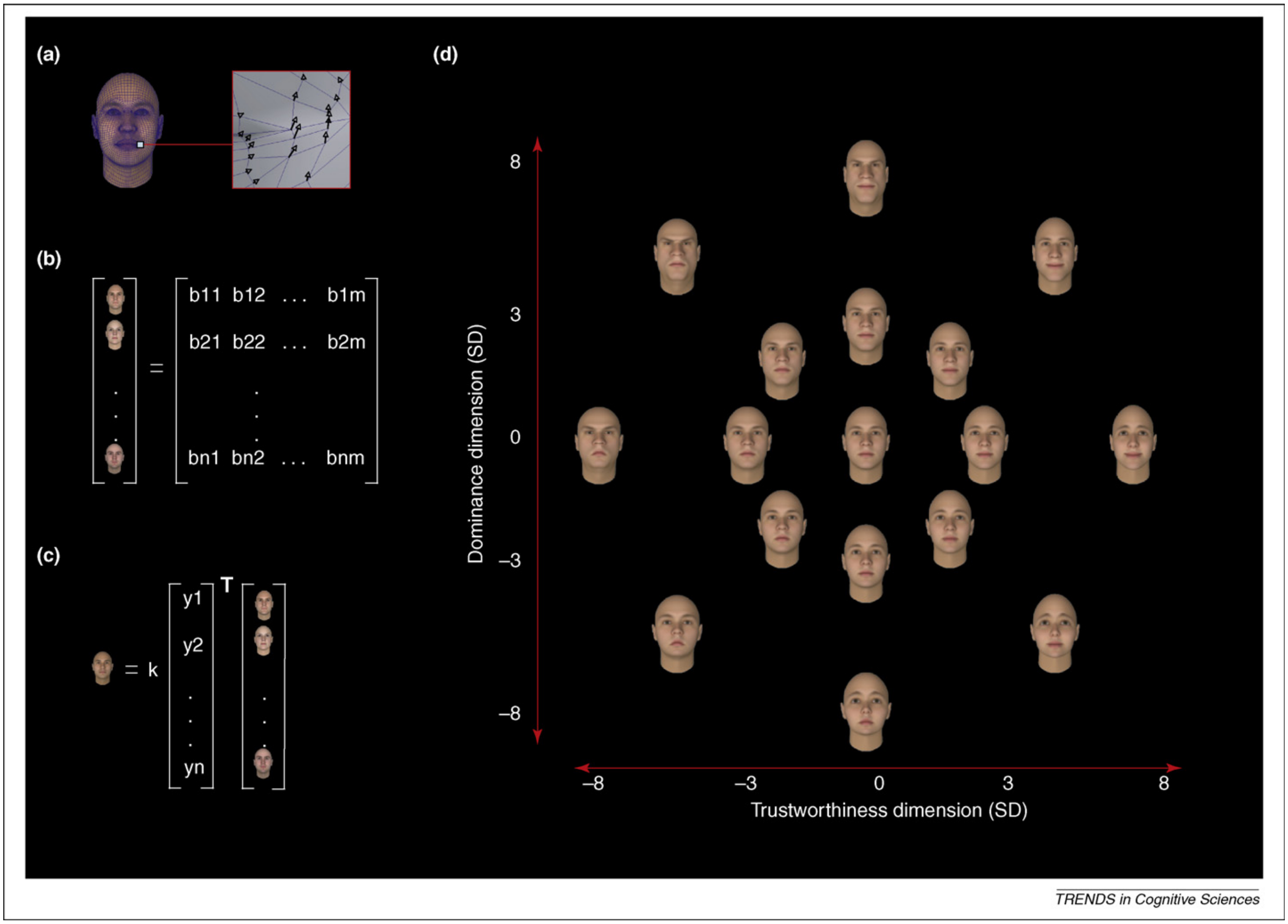


**Figure 2**. Computer modeling of social judgments of faces. **(a)** Illustration of how the face model represents faces (Box 4). A surface mesh with fixed topology superimposed on the average face and linear changes in the vertex positions for the surface of a face segment on one of the $m = 50$ shape dimensions. **(b)** A set of $n$ random faces can be obtained by linear combinations of the 50 shape components. These components are extracted from a principal component analysis of shape variations of the vertex positions and do not necessarily have inherent psychological meaning. **(c)** Each of the $n$ faces is rated by participants on a trait dimension and given an average score $y_j$. Multiplication of the social judgments vector by the set of randomly generated faces yields a dimension that is optimal in changing faces on the trait dimension, which can be controlled with a tunable constant $k$. The figure shows the generation of one face along the trustworthiness dimension. **(d)** A 2D model of evaluation of faces. Examples of a face with exaggerated features on the two orthogonal dimensions – trustworthiness plotted on the $x$-axis and dominance plotted on the $y$-axis – of face evaluation. The changes in features were implemented in a computer model based on trustworthiness and dominance judgments of $n = 300$ emotionally neutral faces [20]. The extent of face exaggeration is presented in SD units. The faces on the diagonals were obtained by averaging the faces on the trustworthiness and dominance dimensions. The diagonal dimension passing from the second to the fourth quadrant was nearly identical to a dimension based on threat judgments of faces. The other diagonal dimension passing from the first to the third quadrant was similar to dimensions empirically obtained from judgments of likeability, extraversion and competence.

judgments of emotional expressions from faces partially covered by randomly located Gaussian windows (bubbles) reveal that, whereas information in the mouth region is diagnostic for identification of happy expressions, information from the eye region is diagnostic for angry expressions [27]. Such approaches could be used to localize the facial cues used for social judgments from emotionally neutral faces.

## The functional basis of face evaluation

In one of the first systematic attempts to understand trait judgments from faces, Secord [28] suggested that such judgments are based on misattribution of momentary states to enduring attributes. Accessible facial cues (e.g. smile) can be generalized to stable dispositions (e.g. friendly). Subsequent theories have emphasized that evaluation of faces is constructed from cues that have adaptive significance [29]. These cues can be either dynamic, expressing emotional states [30], or invariant such as neoteneous facial features (Box 2) and features resembling emotional expressions [31].

Consistent with these theories, the computer modeling findings indicate that evaluating emotionally neutral faces on valence and dominance is an overgeneralization of adaptive mechanisms for inferring behavioral intentions and power hierarchies, respectively. Specifically, subtle resemblance of neutral faces to expressions that signal whether a person should be avoided (anger) or approached (happiness) serves as the basis of valence evaluation. Cues for physical strength such as facial maturity and masculinity serve as the basis of dominance evaluation and are generalized to attributions of related dispositions (Box 2). Functionally, these types of cues – approach or avoidance and strength – give rise to inferences about intentions to cause harm and the ability to implement harm (cf. Ref. [24]).

The overgeneralization hypothesis ([29], Box 2) can account for rapid and efficient, but not necessarily accurate, trait judgments from faces (Box 1), a pattern that would otherwise seem puzzling from an evolutionary point of view. For example, to the extent that these judgments reflect misattribution of cues resembling emotional expressions to stable personality dispositions, they need not be accurate.

## The role of the amygdala in face evaluation

To date, research of the neural mechanisms underlying trait impressions from faces has largely focused on trustworthiness evaluation [11,12,16–19]. These studies have all reported involvement of the amygdala, a subcortical brain region crucial for coding the motivational value of stimuli. Patients with bilateral amygdala lesions show impairments in discriminating trustworthy- from untrustworthy-looking faces [12]. Consistent with these findings, subsequent fMRI studies on healthy individuals have shown that the amygdala response to unfamiliar faces depends on their trustworthiness [16–19]. However, in light of the high correlation between trustworthiness judgments and general valence evaluation of faces (Figure 1), it is possible that the amygdala is most sensitive to face valence, rather than trustworthiness, *per se*. In fact, a recent test of this hypothesis showed that the extent to which variations of faces on trait dimensions engage the amygdala is a function of their valence content: the greater the valence content of a dimension, the stronger the engagement of the amygdala [32].

The amygdala receives input from areas in inferotemporal (IT) cortex and sends output to several visual areas in temporal and occipital cortex, including early visual cortex [33]. Face representations from IT cortex could be sent to the amygdala for affective or motivational evaluation of the faces. As a function of this evaluation, the amygdala can modulate responses in perceptual regions, including early visual cortex, acting as an attention amplifier for motivationally significant faces [34]. Consistent with this hypothesis, the relation between the face response in perceptual regions and face valence was accounted for by the response of the amygdala to face valence [32].

For patients with bilateral amygdala lesions, the affective evaluation of faces is impaired, as manifested in a bias to perceive untrustworthy-looking faces as trustworthy [12]. In contrast to these patients, prosopagnosics with impairments in perception of facial identity show normal trustworthiness judgments [14]. For prosopagnosics, impoverished face representations in IT that are insufficient for face individuation could be sufficient as an input to the amygdala for an affective evaluation of the face, which can explain their normal trustworthiness judgments.

Although initial fMRI studies reported that the amygdala activation increases linearly with the decrease in face trustworthiness [16,17], the response need not be linear or monotonic [18,19] (Box 5). Variables such as the range of trustworthiness of faces and task demands that affect the motivational significance of trustworthy faces could lead to enhanced responses to these positive faces. Both linear and quadratic responses in the amygdala are consistent with a common attentional mechanism according to which the amygdala biases attention towards stimuli that are of current motivational significance to the person [34,35]. Similarly, although the existing findings indicate that the amygdala is engaged primarily in valence evaluation of faces [11,32], it is possible that the amygdala would also be engaged in dominance evaluation when this dimension is motivationally salient.

In addition to anatomical connections to regions in temporal and occipital cortex, the amygdala has anatomical connections to orbitofrontal cortex (OFC). An interesting hypothesis is that affective evaluation of faces in the amygdala not only enhances face processing in perceptual areas [34] but also influences approach and avoidance decisions computed in OFC [36]. This hypothesis is consistent with the computer modeling findings that valence evaluation of faces is grounded in resemblance to expressions signaling approach or avoidance behaviors, in addition to findings that macaque monkeys with bilateral amygdala lesions exhibit uninhibited approach behaviors during social interactions [37].

### Box 5. Outstanding questions

- To what extent does the context of decision affect the processes of face evaluation?
- How do the costs of decision errors (e.g. is it more costly to misjudge a threatening person as non-threatening than to misjudge a non-threatening person as threatening) affect judgmental sensitivity to variations of faces on social dimensions?
- What circumstances determine whether the relation between social judgments and the amygdala will be monotonic or nonmonotonic?
- What are the functional relationships of the amygdala with other structures, particularly frontal decision-making areas?
- How is the amygdala response to faces modified by other sources of person information such as prior information about the person and non-verbal behaviors?
- What are the sources of idiosyncratic, judge-specific contributions to trait judgments of faces?
- Are idiosyncratic judgments subserved by neural systems different from systems that subserve judgments based on face properties that are uniformly perceived across observers?

## Conclusions

We have outlined a general approach to study face evaluation and described a simple 2D model based on this approach. According to this model, when specific decision context is not provided (Box 5), faces are automatically evaluated along the dimensions of valence/trustworthiness and power/dominance. These dimensions define a 2D space within which specific social judgments can be represented [20]. The facial cues used for face evaluation along these dimensions indicate that evaluation of emotionally neutral faces is an overgeneralization of adaptive mechanisms for inferring emotional states with their corresponding behavioral intentions and the ability to implement these intentions.

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