The Dynamic-Interactive Model Approach to the Perception of Facial Emotion

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Traditionally, emotion perception was conceptualized as a direct and effortless "read out" of emotions from specific combinations of facial actions (e.g., Ekman & O'Sullivan, 1988; Nakamura, Buck, & Kenny, 1990). Still today, much research continues to assume that a number of basic emotions are automatically extracted (Tracy & Robins, 2008) and universally recognized (e.g., Matsumoto, Willingham, & Olide, 2009) from a face—although the specific number may be debated. However, a growing body of theory and research has emphasized the strong role that context plays in emotion perception, changing the way we making meaning out of such facial actions to shape perceptions.

For example, at the heart of the conceptual act model of emotion is the premise that physical sensations are implicitly categorized as emotion categories such as "anger" or "fear", a process that requires top-down input from conceptual knowledge of those categories and thereby renders the process of both perceiving and experiencing an emotion highly context-dependent (Barrett, 2006; Lindquist & Barrett, 2008). Evidence for this perspective has often been provided by studies examining the impact of words or other semantic cues on perceptions of facial emotion. For instance, inducing verbal load that impairs the accessibility of specific emotion words has been shown to eliminate emotion categorization tendencies (Roberson, Damjanovic, & Pilling, 2007). Such effects have additionally been observed in clinical populations suffering from reduced semantic retrieval ability, such as semantic aphasia (Roberson, Davidoff, & Braisby, 1999). In semantic satiation tasks where an emotion word is rapidly repeated until rendered meaningless for a short period of time, the perceptual discriminability of facial emotion suffers (Lindquist et al., 2006). Accordingly, researchers have interpreted these effects to reflect the importance of conceptual knowledge and implicit categorization in the process of perceiving facial emotion.

Understanding emotion perception as an active, constructive process (wherein top-down conceptual knowledge is used to build a representation of facial emotion) rather than a passive "read out" of facial action units opens the door to its impact by a variety of contextual factors. Top-down knowledge and contexts appear to play a considerable role in emotion perception when the bottom-up perceptual signal is weak, as in cases of emotion ambiguity—although such influences are hardly limited to these cases (Barrett, 2006). It is also important to note that in many emotion perception studies, the facial expressions used are often be extreme and unnatural.

In the real world, emotional expressions are rarely extreme and obvious. Rather, if cropped in isolation, a typical facial emotional expression is usually a blend between multiple interpretable emotions (e.g., could be slightly angry or slightly happy), and perceivers often require contextual cues extraneous to the face to appropriately perceive and understand others (Aviezer et al., 2008a; Russell, 1997; Scherer & Tannenbaum, 1986; Wallbott, 1988).

When perceivers are confronted by more natural, blended emotional expressions, context appears to play a large role in perception. In one study, participants encoded emotionally ambiguous faces while given a semantic context (an explicit label such as “angry” or “happy”; Halberstadt & Niedenthal, 2001). Faces that were paired with an angry label were subsequently remembered as more angry, just as faces paired with a happy label were remembered as more happy. Further data ruled out the possibility that these context influences were due to post-perceptual processes (Halberstadt et al., 2009; Halberstadt, 2005). This suggested that participants visually encoded the emotional expressions according to their context label, which led to systematically biased, context-altered memory later. Not only does a semantic context constrain the manner by which facial emotion is perceived, but this holds true for other visual context cues that surround the face. For instance, incongruence between facial emotion and emotional cues of the body leads to delayed emotion-categorization latencies (Meeren, van Heijnsbergen, & De Gelder, 2005). In a compelling set of studies, Aviezer et al. (2008b) presented participants with the same exact face stimuli that were embedded in different body contexts suggesting particular emotions. Judgments of identical emotional expressions were strikingly influenced by contextualizing emotional body cues. Thus, visual contexts surrounding a face, such as emotional body cues, seamlessly alter perceptions of facial emotion.

The Dynamic-Interactive Model of Social Categorization

In this chapter, I outline a dynamic social categorization approach to the perception of facial emotion, making use of theoretical insights from our Dynamic-Interactive (DI) Model, a computational model of social categorization (Freeman & Ambady, 2011a). It complements recent approaches more traditionally focused on emotion perception, such as the conceptual act model (Barrett, 2006). The DI Model focuses on the processing dynamics underlying the real-time perception of social categories (e.g., gender, race, age, emotion) and how they are influenced not only by bottom-up cues originating in the target of perception (e.g., facial cues) but also by top-down social factors harbored within the perceiver (e.g., stereotypes, goals, and motives). Thus, one assumption at the heart of the DI Model is that multiple top-down processes impinge on the visual perception of faces' social categories, including stereotypes (Freeman et al., 2011b; Johnson, McKay, & Pollick, 2011), motives (Caruso, Mead, & Balcetis, 2009; Krosch & Amodio, 2014; Ratner et al., 2014), and prior person-knowledge (Anderson et al., 2011; Freeman et al., 2010c). By biasing the early visual perception of faces, such influences often in turn impact evaluative biases (Freeman, Pauker, & Sanchez, invited revision) and downstream behaviors (Krosch & Amodio, 2014; Ratner et al., 2014).

The general model appears in Figure 1. It is a recurrent connectionist network with stochastic interactive activation. Details about the model can be found in Freeman and Ambady (2011). In the model, social categorization is treated as an ongoing, dynamic process where bottom-up cues and top-down factors interact over time to stabilize onto particular categorical percepts (e.g., Black, White, Asian), including emotion categories (e.g., angry or happy). This is because social categorizations, as implemented in a human brain, would involve continuous changes in a pattern of neuronal activity (Freeman et al., 2011a; Spivey & Dale, 2006; Usher & McClelland, 2003). Early in processing, representations of the face would tend to be partially consistent with multiple categories (e.g., both angry and happy) because the initial rough "gist" of the face partially supports both categories. As more information accumulates, the pattern of neuronal activity would gradually sharpen into an increasingly confident representation (e.g., angry), while other competing, partially-active representations (e.g., happy) would be pushed out. During the hundreds of milliseconds it takes for the neuronal activity to achieve a stable pattern (~100% angry or ~100% happy), both bottom-up processing of the face as well as top-down factors (e.g., conceptual knowledge or stereotypes) could gradually exert their influences, jointly determining the pattern to which the system gravitates. Thus, this approach proposes that emotion perception involves dynamic competition between partially-active emotion categories (e.g., angry and happy). Further, the competition is gradually weighed in on by both bottom-up facial cues as well as top-down social factors, until a stable categorization is achieved. As such, bottom-up cues and top-down factors mutually constrain one another to form a 'compromise' over time and thereby shape basic perceptions of faces.

The model is naturally quite consistent with other recent approaches to emotion perception described above, emphasizing the role of top-down conceptual knowledge and context. The DI Model can account for a wide range of effects in social categorization. With respect to emotion, it predicts that: 1) like other social categorizations, the perception of emotion categories is readily influenced by top-down conceptual knowledge, e.g., stereotypes, but also more nuancedly that 2) such top-down impacts render emotion perception inherently intersectional and tethered to gender, race, age, and other social categories. The reason for the intersectional nature of emotion representation would be that stereotypes, once automatically and implicitly activated from facial cues, can throw different category memberships into interaction with one another. For instance, the perception of emotion categories can become inextricably linked to ostensibly unrelated categories (e.g., race and gender) even down to the visual level, because their mutually-shared stereotypes cause the categories to become perceptually entangled.

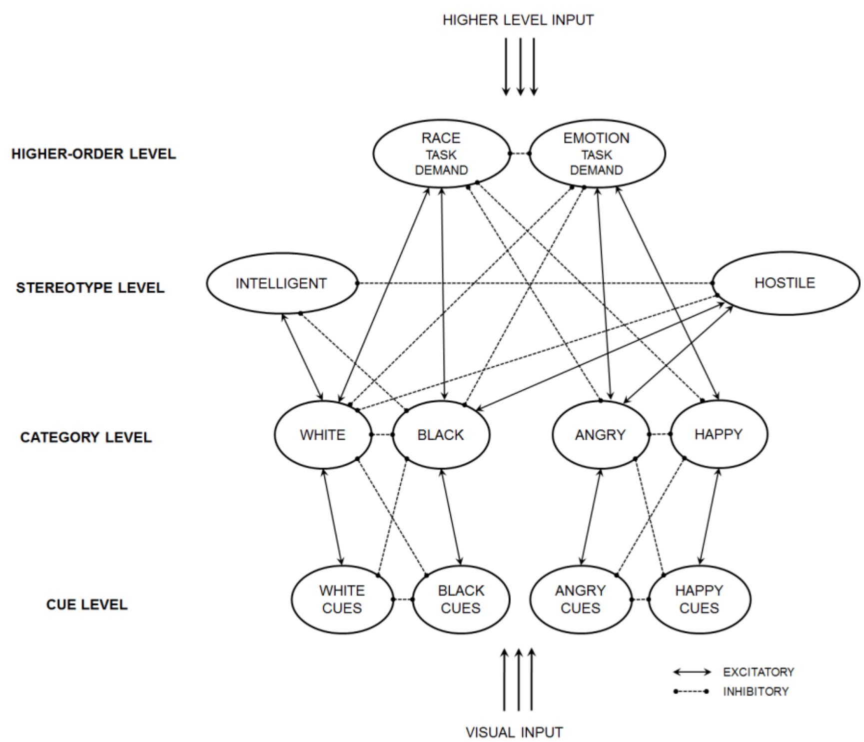

Figure 1. One instantiation of the DI Model. Note the mutually shared stereotype (hostile) between ostensibly unrelated race and emotion categories (Black and angry). This is argued to cause visual perception of Black faces to be biased toward angry.

The Entangled Nature of Emotion Categories

Previous research has shown that seemingly unrelated social categories which incidentally share stereotypes (e.g., Black and male both associated with hostile) facilitate each other's perceptions (Carpinella et al., 2015; Freeman & Ambady, 2011a; Johnson, Freeman, & Pauker, 2012), an effect that has been linked to a variety of consequences ranging from interracial marriage to leaders' election (Galinsky, Hall, & Cuddy, 2013). Such category entanglement also occur with emotion perception. Consider one particular instantiation of the DI Model in Figure 1. Because the male and angry categories both share associations with the hostile stereotype, facial cues belonging to one category (e.g., Black) will facilitate the perception of certain emotion categories (e.g., angry). Specifically, Black-related facial cues will begin activating the Black category, which will begin activating related stereotypes that then become an implicit expectation that then guides the categorization process. Activation from stereotypes can then, via the recurrent feedback intrinsic to this dynamic system, return back to category representations and shape their activation—even ones that did not initially activate the stereotype. Thus, for example, when processing a Black face with a happy expression, race-triggered stereotypes may become activated that immediately impose a top-down constraint on the emotion categorization process, biasing it toward an angry interpretation. Overall, such work suggests that the visual perception of emotion categories is the end-result of a malleable process wherein bottom-up facial cues and top-down stereotypes form a "compromise" over time. In turn, this process of negotiation thereby renders emotion perception fundamentally intersectional and tethered to other categories with which it shares associations (e.g., angry-Black, angry-male, happy-female).

Early work on this issue showed that racially-ambiguous faces are more readily perceived as Black when displaying anger, and that emotionally-ambiguous faces are more readily perceived as angry when Black. These effects became more pronounced in individuals with higher levels of implicit race bias, who are known to activate stereotypes more readily (Hugenberg & Bodenhausen, 2003; Hugenberg & Bodenhausen, 2004). Even for non-ambiguous faces, more recent mouse-tracking studies have shown that the categorization process for stereotypically incongruent faces (e.g., happy Black face) is biased early on toward the stereotypically associated interpretation (e.g., angry); this is then resolved (e.g., happy) over the next hundreds of milliseconds (e.g., Hehman, Ingbretsen, & Freeman, 2014; Figure 2). Similar effects have also been observed with gender and emotion categories, as men are stereotyped as more aggressive and angry, and women are stereotyped as more appeasing and happy. Accordingly, previous work has shown that these stereotypical associations result in facilitated perceptions of angry male and happy female faces (Hess, Adams, & Kleck, 2004; Hess et al., 2000). Computational simulations with various instantiations of the DI Model account well for these effects of entangled perceptual effects (Freeman & Ambady, 2011a).

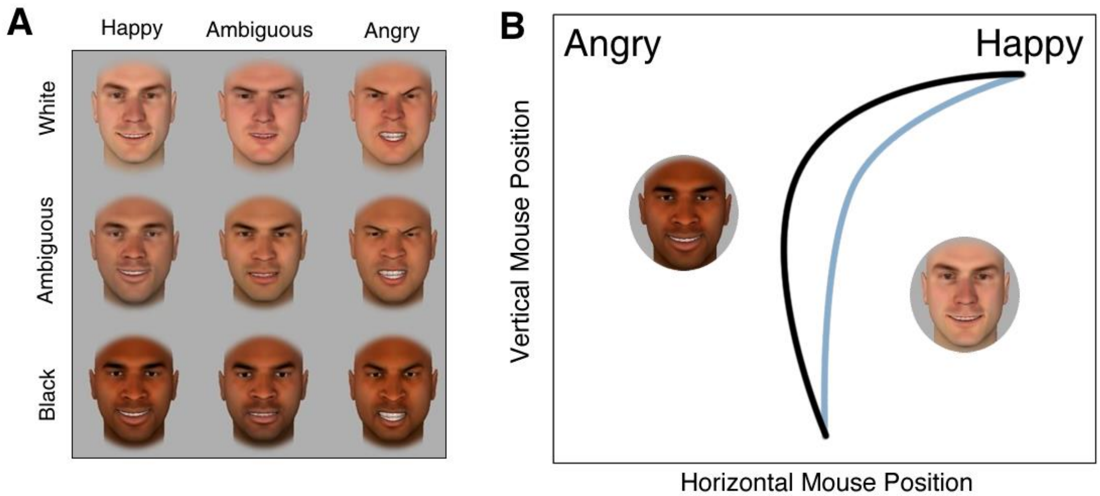

Figure 2. (A) Morphed faces independently varying in race and emotion, as used in Hehman et al. (2015). (B) Schematic depiction of one idealized pattern of results from the mouse-tracking tasks used in Hehman et al. (2015) and Stolier and Freeman (invited revision). Although participants explicitly categorized Black faces with happy expressions as “Happy”, their mouse trajectories were initially drawn to select the “Angry” response due to implicit stereotypes.

We recently explored the neural mechanisms underlying such intersectional emotion perception. We were especially interested in the impact of stereotypes and social-conceptual knowledge on visual representations of faces; how “deep” does such biasing reach into the visual system? Naturally, of special concern to us was the fusiform gyrus (FG), a region centrally involved in face perception (Haxby, Hoffman, & Gobbini, 2000; Kanwisher & Yovel, 2006) and processing face-based categorical distinctions (Freeman et al., 2010b; Rotshtein et al., 2005), and its interplay with higher-order brain regions that might affect the visual processing of facial emotion categories. In an initial neuroimaging study (Hehman et al., 2014), we asked participants to passively view faces independently varying along race (from White to Black) and emotion (from happy to angry). Following the scan, they completed emotion and race categorization mouse-tracking tasks. In such tasks, participants begin a trial by clicking a start button at the bottom-center of the screen. A stimulus is then presented (in this case, a face), and participants must rapidly categorize the stimulus by moving the cursor from the bottom-center of the screen to the responses in either top corners of the screen (e.g., "Angry" vs. "Happy"). Despite the explicit response, in such tasks participants often exhibit initial deviation and a tentative attraction toward the unselected response (on the opposite side of the screen) before stabilizing on the selected response. This can occur due to a number of psychologically interesting factors. Namely, in social categorization mouse-tracking tasks, effects may arise from bottom-up factors inherent in the target, e.g., when a face bears subtle cues belonging to the opposite category (Freeman & Ambady, 2011b; Freeman et al., 2010a). They may also arise from top-down factors harbored within the perceiver, e.g., when the opposite category is associated with an implicit stereotypic expectation (Freeman et al., 2011b). In this case, this task was used as an index of the extent to which racial stereotypes influenced emotion perception (e.g., the hand's initial attraction to select "Angry" for a Black face with a happy expression).

At the neural level, we found that as faces increased in stereotypic incongruency (e.g., a Black face became happier or a White face became angrier), the anterior cingulate cortex (ACC), a region important for conflict monitoring (Botvinick et al., 2001), showed correspondingly stronger responses and stronger functional connectivity with the FG. Moreover, the dorsolateral PFC (dlPFC), a region implicated in inhibiting automatic responses (MacDonald et al., 2000), showed increased activation to stereotypically incongruent emotions (e.g., happy Black face), and this effect was exacerbated for those participants whose emotion perception was most stereotypically biased (as assessed with the mouse-tracking task). Thus, one interpretation is that the ACC may help resolve the conflict between the bottom-up cue-driven interpretation (e.g., happy, for a happy Black face) and the top-down stereotype-driven interpretation (e.g., angry, for a happy Black face). This, in turn, may lead to greater cross-talk with the FG to help resolve the conflict (e.g., by receiving more perceptual input of the face). The dlPFC may then have been involved in inhibiting the top-down, stereotype-based interpretation (e.g., angry Black) to allow the more veridical, cue-based interpretation (e.g., happy Black) from the FG to win out. Together, such results suggest an important interplay between face-processing regions such as the FG and higher-order regions involved in conflict-monitoring and inhibition (ACC and dlPFC, respectively) in automatically inhibiting stereotype-driven interpretations of a face's social categories, permitting perceivers to see them for what they "actually" are (Hehman et al., 2014).

Recently, we sought to more directly examine how a face's emotion categories are represented, particularly how such representations may become influenced by one's stereotypes and inextricably linked to race and gender representations. To do so, we adopted a multi-voxel pattern analysis approach, which allowed us to inspect unique neural patterns that code for particular face properties within brain regions, rather than inspect a region's overall engagement (using mean activation). In two neuroimaging studies (Stolier & Freeman, invited revision), participants passively viewed faces that independently varied on emotion, race, and gender categories. Following the scan, participants completed mouse-tracking tasks, indexing the extent to which a face activated ostensibly unrelated social categories due to shared stereotypes (e.g., to what extent male faces were implicitly perceived to be more similar to angry than happy faces). They also complete a stereotype task allowing us to measure how much conceptual knowledge overlapping between pairs of emotion, gender, and race categories.

We found that stereotypically biased similarities between categories during real-time perceptions (e.g., male-angry, female-happy, Black-angry) were reflected in the similarity of the categories' multi-voxel representations in the FG and orbitofrontal cortex (OFC). Importantly, these biased FG and OFC patterns held true even when controlling for possible visual resemblances and when faces were matched on low-level visual properties. Previous work has shown the OFC to be involved in generating implicit expectations from stereotypes (Knutson et al., 2007) or social context (Freeman et al., 2015), a process selectively impaired by OFC damage (Milne & Grafman, 2001). The OFC has also long been implicated in top-down visual predictions that facilitate object recognition (Bar, 2004; Barrett & Bar, 2009; Summerfield & Egner, 2009). The results are therefore quite consistent with the premise that, on viewing a face, the OFC may be involved in accessing implicit stereotypes that are then fed back to sensitize FG visual face representations in line with expectations. This is further supported by our finding of increased OFC-FG functional connectivity during face processing in the two studies.

Finally, we also found the OFC patterning was also sensitive to individual differences in stereotype overlap; for example, participants who did not exhibit strong overlaps (e.g., Black-angry, male-angry, female-happy) showed less biased OFC patterns. By and large, however, multi-voxel representations in the FG and OFC associated with 'Black' and 'male' were systematically closer to 'angry', and those associated with 'female' were systematically closer to 'happy', in a manner correlated with subjective perceptions and unexplainable by visual similarities. As mentioned, however, these brain regions also reflected individual differences in the specific biases observed in a participant's subjective perceptions. Together, such findings suggest that the visual representations of faces in the FG become biased by one's implicit stereotypical expectations (activated by seemingly unrelated social categories), and that such biased visual representations may be driven by top-down modulation from the OFC. As such, the brain's representation of emotion categories is inherently tied up in its representation of gender and race categories (Stolier & Freeman, invited revision). This work specifies the neural representations underlying the well-documented behavioral effects of entangled perceptions of social categories. Consistent with the DI Model's predictions, such biasing effects travel quite "deeply" at a perceptual level, affecting FG patterns involved in visual processing of a face.

Conclusion

Recent theory and research has highlighted the role of context and conceptual knowledge in shaping emotion perception. The DI Model of social categorization complements these approaches to emotion by additionally emphasizing such top-down impacts, and specifying computationally how bottom-up facial cues may come to form compromises with conceptual knowledge, stereotypes, or motives to shape emotion perception. One unique prediction arising from this approach is the inherently intersectional nature of emotion perception, where perceptions of facial emotion categories become entangled with race and gender categories via top-down stereotypical associations that bind these categories together. Thus, in the growing interest of contextual impacts on emotion perception, context can be conceived to include the "context" of other category memberships within the face itself, such as gender, race, age, or other social categories that are conceptually linked to emotion categories.

Such intersectional emotion perception is predicted from the model and now supported by much behavioral evidence, including studies using implicit behavioral techniques such as mouse-tracking. These impacts on visual perception of emotion categories appear to seep quite low into the brain's visual processing of faces, reflected in neural representations in basic face-perception mechanisms such as the FG. The evidence thus far suggests that these FG face representations may be top-down modulated by representations in the OFC, a region implicated in accessing implicit stereotype knowledge. In cases where bottom-up facial cues directly conflict with a top-down stereotype-based interpretation, conflict-monitoring and inhibitory mechanisms (ACC and dlPFC, respectively), and their interaction with FG face processing, also appear to be important, allowing a veridical representation of a face to come to the fore.

In summary, these insights and the DI Model approach to emotion perception may prove useful in the growing interest of context and conceptual processes in perceiving emotions. Although a model of social categorization rather than emotion perception per se, what is clear from the approach is that emotion perceptions do not occur in isolation. Besides acknowledging the role of conceptual knowledge, language, and extraneous contextual cues, it is also important to consider the "context" within the very face itself. This work shows that, due to top-down conceptual feedback, emotion categories can become inherently entangled with seemingly unrelated dimensions in ways that alter the visual representation of facial emotion. At a broader level, this work demonstrates the highly dynamic and malleable process that is emotion perception. Indeed, it is in such a way that divisions between it and other social categorizations are not so clear.

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