Visual Attention, Bias, and Social Dispositions Toward People With Facial Anomalies

A Prospective Study With Eye-Tracking Technology

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Background: Facial attractiveness influences our perceptions of others, with beautiful faces reaping societal rewards and anomalous faces encountering penalties. The purpose of this study was to determine associations of visual attention with bias and social dispositions toward people with facial anomalies.
Methods: Sixty subjects completed tests evaluating implicit bias, explicit bias, and social dispositions before viewing publicly available images of preoperative and postoperative patients with hemifacial microsomia. Eye-tracking was used to register visual fixations.
Results: Participants with higher implicit bias scores fixated significantly less on the cheek and ear region preoperatively ($P = 0.004$). Participants with higher scores in empathic concern and perspective taking fixated more on the forehead and orbit preoperatively ($P = 0.045$) and nose and lips ($P = 0.027$) preoperativel.
Conclusions: Participants with higher levels of implicit bias spent less visual attention on anomalous facial anatomy, whereas participants with higher levels of empathic concern and perspective taking spent more visual attention on normal facial anatomy. Levels of bias and social dispositions such as empathy may predict layperson gaze patterns toward those with facial anomalies and provide insights to neural mechanisms underlying the "anomalous is bad" paradigm.

Key Words: eye-tracking, hemifacial microsomia, bias, empathy, visual attention

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Our faces are important for forming impressions and have an impact on perceptions of social characteristics.[1] Previous studies characterized relations between facial beauty and positive character traits, including perceived health and trustworthiness.[2,3] Recent research has reported associations between facial anomalies and perception by observers as having negative social characteristics (eg, anger, untrustworthiness, unfriendliness). Collectively, the social penalties associated with facial anomalies have been described as the "anomalous-is-bad" bias.[4–6]

Assessment of visual attention provides unique insight into uninhibited behavior.[7] Eye-tracking technology has been increasingly used in the past decade to evaluate how people deploy visual attention toward those with facial differences.[8] Studies generally find that visual attention is drawn toward anomalous anatomy[9] and that the degree of visual attention correlates with the severity of the pathology or anomaly.[10] Hemifacial microsomia (HFM) is an optimal condition for studying gaze patterns because of its effects on specific facial regions, most commonly the mandible, chin, and ear.[11]

Recent work with functional magnetic resonance imaging has implicated certain neuroanatomic structures when viewing others with facial anomalies.[6] Laypersons with high levels of implicit bias toward those with facial anomalies demonstrated increased amygdala reactivity.[6] Although previous studies have used eye-tracking to characterize visual attention toward patients with craniofacial anomalies, visual attention has not been analyzed alongside assessments of biases and other social dispositions. This study aimed to characterize associations between visual attention patterns and implicit biases (attitudes toward groups of people without conscious awareness) and explicit biases (attitudes toward groups of people with conscious awareness), as well as social dispositions toward people with facial anomalies. We hypothesized that visual attention toward people with facial anomalies differs as a function of implicit bias. Specifically, we predicted visual attention would be directed away from areas of facial anomalies in those with high levels of implicit bias.

METHODS

Study Population

For this prospective study, participants were recruited through University of Pennsylvania's MindCORE SONA, a system used to recruit members of the University of Pennsylvania and the Philadelphia metropolitan area for research studies. Participants completed a prescreening form that assessed eye-tracking study ineligibility, including the presence of medical devices impacted by infrared light and a medical history of photogenic epilepsy. Participants were 18 years or older, spoke English, and had no major visual impairments. Participants were compensated US $20 per hour, and study visits were on average 1 hour in duration. Participants were naive to the study design and authors' null hypotheses. At the beginning of the in-person study visit, participants completed written informed consent, where the study risks, benefits, and aims were described. This study was approved by the Institutional Review Board at the University of Pennsylvania Perelman School of Medicine.

Social Dispositions

Before the in-person study visit, eligible subjects provided demographic information and completed surveys to assess social dispositions: Interpersonal Reactivity Index (IRI),[12] Procedural and Distributive Just World Belief Scale (JWBS),[13] Social Dominance Orientation Scale (SDO),[14] and Three-Domain Disgust Scale (TDDS).[15]

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The IRI assessed empathic concern (assessing feelings of sympathy and concern for others who are less fortunate) and perspective-taking (assessing tendency to adopt the psychological point of view of others) using a 1–5 scale of "does not describe me well" to "describes me very well."[16] The JWBS assessed "procedural" and "distributive" just world beliefs about others using a 1–7 Likert scale.[13] The SDO measured support for social hierarchy and the desire for in-group superiority relative to out-groups.[14] The TDDS assessed domains of pathogen (eg, stepping on dog poop), moral (eg, deceiving a friend), and sexual (eg, hearing 2 people having sex) disgust.[15]

Eye-Tracking and Stimuli

Participants in this study viewed 17 publicly available front-facing pairs of patients precorrective and postcorrective jaw surgery for HFM.[17] Images were standardized in size and applied to black backgrounds.[18] Images were presented in right-to-left and left-to-right orientation to correct for left gaze bias and to improve statistical power.[19–23]

Participant visual fixations were captured with the Tobii Pro Nano eye tracker. Participants completed 2 trials of an eye-tracking task with brief calibration (approximately 60 seconds) before each run. Calibration for this experiment involved tracking targets to 9 locations on the screen—4 outermost corners, 4 corners more central to the screen, and the central most point of the screen. A total of 68 images were presented for 5 seconds each in a pseudorandomized fashion, both regarding order of appearance and the side of the screen on which it appeared.[22] Participants were instructed to look at a centralized white "+" on a black background between each image for 1.5 seconds to recenter gaze before the subsequent image. Each trial was designed to last approximately 10 minutes total.

Four areas of interest (AOIs) were defined on each face: cheek and ear, forehead and orbit, mandible and chin, and nose and lips. The number of visual fixations was quantified in each AOI. Visual fixations were defined as a visual gaze in a single location for 200 milliseconds or longer.

Implicit Association Test and Explicit Bias Questionnaire

Participants completed an Implicit Association Test (IAT) in a standard manner.[24,25] This procedure consisted of 7 parts, where they associated words with positive connotations with nonanomalous faces and words with negative associations with anomalous faces.[24,25] First, participants pressed keys to categorize faces as anomalous or typical. Second, using the same keys, participants categorized words as "good" (eg, happy) or "bad" (eg, sickening). Third, participants used the same keys to categorize both faces and words (eg, anomalous faces and good words, typical faces and bad words). The fourth part replicated the third. In parts 5 through 7, the mapping between faces and keys was swapped (eg, such that anomalous faces were paired with bad words, and typical faces were paired with good words).

The average reaction time when associating anomalous faces with bad words (and typical faces with good words as in part 7) was subtracted from the average reaction time when associating anomalous faces with good words (and typical faces with bad word as in part 4). This difference was divided by the standard deviation to calculate the IAT score. Participants who were faster at associating anomalous faces with bad words had positive IAT scores, indicating implicit bias. As quality control, error rates could not exceed 30% of trials (ie, 10 or more), and latencies could not drop below 300 milliseconds in over 10% of trials (ie, 4 or more). Trials with latencies exceeding 10 seconds or falling below 400 milliseconds were also removed.

Finally, participants completed an Explicit Bias Questionnaire (EBQ), a 33-item questionnaire about people with facial anomalies using a 1–7 Likert scale (Supplemental Table 1, http://links.lww.com/SAP/A816).

Statistical Analyses

Linear mixed effects models (LMEMs) tested whether locations of participant fixations were affected by surgical correction of HFM and influenced by IAT, EBQ, or social disposition scores. Social dispositions included in the LMEM analyses were selected based on previous research[22,26] and included IRI empathic concern, IRI perspective taking, SDO, JWBS procedural and distributive toward others, and TDDS pathogen disgust.

Bias and social disposition data were assessed for normality with Shapiro-Wilk tests. Data that were not normally distributed were transformed with Tukey Ladder of Powers in RStudio, a validated method to transform data to achieve normal or near-normal distributions.[26]

Null models were estimated with Akaike information criterion values, an estimation of prediction error.[27] Models with higher Akaike information criterion values relative to the null models were determined to be nonpredictive. Statistical significance was defined as $\alpha = 0.05$ (2-tailed). Participants were excluded if they self-reported poor-quality data,[28] failed 2 or more attention checks in the social domain assessments, or had poor quality eye-tracking data (repeatedly under 80% of visual fixations captured). All statistical analyses were performed in RStudio 1.3 (The R Foundation for Statistical Computing, Vienna, Austria). The LmerTest R package was used for linear mixed effects modeling.[29] This study was preregistered with Open Science Forum (https://osf.io/9kvtg/?view_only=784c05f00f84496c8af9e103f6c0254f).

RESULTS

Participant Demographics

Sixty laypersons were included in this study (Table 1), with an average age of 26.2 ± 7.3 years (range, 19–59). Participants were mostly women (n = 38, 63.3%) and White (n = 36, 60.0%).

Data Quality and Calibration

Data quality was assessed with the Tobii Pro Lab software package. The average trial length was 9.16 ± 0.56 minutes, including the calibration phase(s). The average percentage of visual fixations captured per trial was 93.6% ± 4.1% (range, 82%–99%). Participants repeated trials with under 80% of visual fixations captured.

The average calibration accuracy was 0.63 ± 0.81 degrees, 6.08 ± 2.81 mm, and 60.9 ± 78.3 px. The average validation accuracy was 0.53 ± 0.73 degrees, 4.82 ± 5.86 mm, and 48.23 ± 58.71 px. The average validation precision was 0.34 ± 0.47 degrees, 3.19 ± 4.37 mm, and 31.9 ± 43.8 px.

Biases and Social Disposition Results

Sixty participants completed the IAT, with 58 passing the quality assessment. The IAT scores ranged from −1.10 to 1.10 (most biased) with an average score of −0.04 ± 0.68 (Table 2). The EBQ scores ranged from 2.29 to 5.14 (most biased) with an average score of 3.97 ± 0.65. Results of the social disposition tests are detailed in Table 2.

Visual Fixations

A total of 47,354 visual fixations were captured over 120 trials within defined AOIs. Across all participants and stimuli (preperative and postoperative), nearly half (n = 23,350, 49.3%) of all visual fixations fell within the forehead and orbit, and approximately one third of fixations (n = 17,031, 36.0%) fell within the nose and lips, with the remainder in the cheek and ear (n = 5666, 12.0%) and mandible and chin (n = 1307, 2.8%).

TABLE 1. Participant Demographics

	n (%)
Total participants	60
Sex assigned at birth	
Female	38 (63.3)
Male	22 (36.7)
Gender identity	
Female	34 (56.7)
Male	23 (38.3)
Trans/gender nonconforming	3 (5.0)
Race*	
White	36
Asian	25
Black/African American	11
American Indian	0
Other	1
Prefer not to answer	2
Ethnicity	
Not Hispanic or Latino	54 (90.0)
Hispanic or Latino	6 (10.0)
Sexuality	
Heterosexual	37 (61.7)
Bisexual	9 (15.0)
Lesbian, gay, or homosexual	6 (10.0)
Queer	3 (5.0)
Asexual	2 (3.3)
Pansexual	1 (1.7)
Prefer not to answer	2 (3.3)
Handedness	
Right	54 (90.0)
Left	6 (10.0)
Average age (SD)	26.2 (7.3)
Average years of education (SD)	16.6 (2.6)

*Participants may select more than one race

TABLE 2. Tests of Biases and Social Dispositions

Implicit bias	−0.04 ± 0.68
Explicit bias total	3.97 ± 0.65
Is disabled	7 (11.7)
Has facial anomaly	0 (0)
Disabled family member	21 (35.0)
Family facial anomaly	11 (18.3)
Social dominance orientation	3.91 ± 0.46
JWBS: distributive others	3.15 ± 1.46
JWBS: procedural others	3.11 ± 1.29
IRI: empathic concern	3.25 ± 0.28
IRI: perspective taking	3.37 ± 0.45
TDDS: moral	32.78 ± 6.66
TDDS: sexual	23.78 ± 8.47
TDDS: pathogen	31.08 ± 6.88

Values reported in mean ± SD or n (%).

Visual Fixations, Biases, and Social Disposition Analyses

The LMEMs evaluated interactions between biases and social disposition scores with preoperative and postoperative status to influence visual fixations in AOIs. Participants with higher IAT scores fixated significantly less on the cheek and ear region preoperatively compared with postoperatively (β = 0.115, SE = 0.040, z = 2.855, *P* = 0.004) (Table 3). Implicit Association Test scores did not influence participant visual fixations in other AOIs. The EBQ scores did not significantly influence visual fixations in any AOIs based on better fit to the null models.

Participants with higher IRI scores in empathic concern and in perspective taking did show differences in their gaze patterns across presurgical and postsurgical faces. However, their visual attention did not vary across both conditions for the anomalous portions of the face. Rather, people with higher scores on empathic concern fixated more on the forehead and orbit preoperatively compared with postoperatively (β = −0.107, SE = 0.053, z = −2.007, *P* = 0.045), and participants with higher IRI scores in perspective taking fixated more on the nose and lips (β = −0.085, SE = 0.038, z = −2.215, *P* = 0.027) preoperatively compared with postoperatively. Scores on procedural JWBS toward others, distributive JWBS toward others, social dominance orientation, and

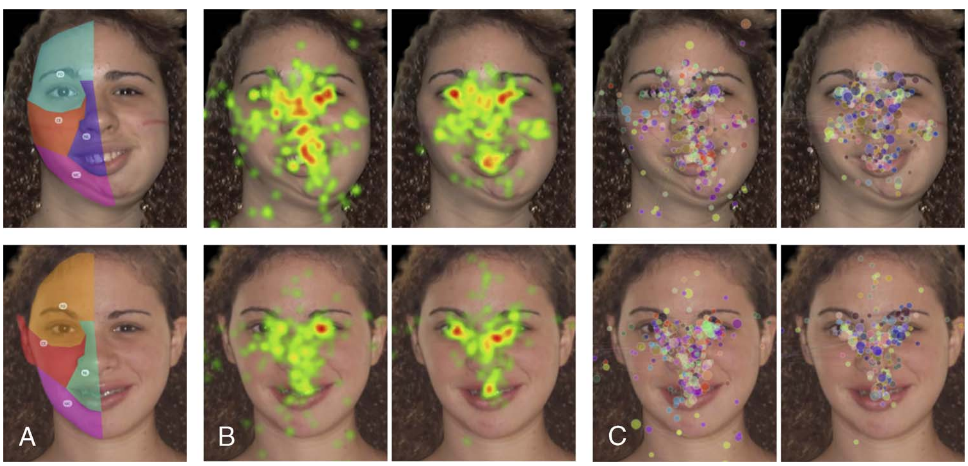

FIGURE 1. Example stimuli preoperative (top) and postoperative (bottom) with (A) demarcated areas of interest (AOIs); (B) heat maps for number of visual fixations; and (C) duration of visual fixations for ten participants with highest (left) and lowest (right) implicit bias scores. full color online

TABLE 3. Interactions of Biases or Social Dispositions With Visual Fixations by Area of Interest

Fixed Effects	β	SE	*Z*	*P*
Implicit Bias Association Test				
Forehead and orbit	0.015	0.023	0.627	0.531
Cheek and ear	0.115	0.040	2.855	0.004**
Nose and lips	−0.005	0.025	−0.203	0.839
Mandible and chin	−0.066	0.079	−0.837	0.402
EBQ				
Forehead and orbit	0.000	0.001	−0.137	0.891
Cheek and ear	−0.001	0.002	−0.336	0.737
Nose and lips	0.000	0.001	−0.142	0.887
Mandible and chin	0.002	0.004	0.512	0.609
IRI: empathic concern				
Forehead and orbit	−0.107	0.053	−2.070	0.045*
Cheek and ear	0.132	0.102	1.291	0.197
Nose and lips	−0.017	0.060	−0.289	0.772
Mandible and chin	0.168	0.203	0.829	0.407
IRI: perspective taking				
Forehead and orbit	−0.009	0.034	−0.256	0.798
Cheek and ear	0.001	0.059	0.011	0.991
Nose and lips	−0.085	0.038	−2.215	0.027*
Mandible and chin	0.159	0.124	1.294	0.196
JWBS: procedural				
Forehead and orbit	−0.007	0.012	−0.602	0.547
Cheek and ear	0.003	0.020	0.126	0.900
Nose and lips	−0.019	0.013	−1.400	0.161
Mandible and chin	0.025	0.041	0.606	0.544
JWBS: distributive				
Forehead and orbit	0.006	0.01	0.545	0.586
Cheek and ear	−0.014	0.019	−0.712	0.477
Nose and lips	−0.008	0.012	−0.741	0.459
Mandible and chin	0.034	0.037	0.936	0.349
Social dominance orientation				
Forehead and orbit	−0.003	0.032	−0.100	0.920
Cheek and ear	−0.077	0.060	−1.274	0.203
Nose and lips	0.013	0.035	0.377	0.706
Mandible and chin	0.160	0.136	1.173	0.241
Three domains of disgust: pathogen				
Forehead and orbit	0.004	0.002	1.722	0.085
Cheek and ear	−0.001	0.004	−0.353	0.724
Nose and lips	−0.002	0.002	−0.924	0.356
Mandible and chin	−0.007	0.009	−0.760	0.447

pathogen disgust did not significantly interact with preoperative or postoperative status to influence participant visual fixations.

DISCUSSION

Our faces influence others' perceptions of our social characteristics, including trustworthiness, happiness, and confidence,[1,31,32] with the "beauty-is-good" stereotype underlying the relationship between attractive faces and positive character trait attributions.[32] Recent studies have described neural mechanisms underlying a complementary "anomalous-is-bad" bias and implicated specific neuroanatomic structures in the processing of anomalous faces, particularly the amygdala.[6,34] This previous work also quantified relations between levels of implicit bias and social dispositions (ie, empathic concern) with the strength of these neuroanatomic responses.[6] Gaze patterns and visual attention have previously been used to study laypeople's perceptions of craniofacial anomalies. Eye-tracking is one such mechanism of objectively characterizing craniofacial anatomy,[35] in addition to other mechanisms including crowdsourcing[36,37] and soft tissue analysis.[38] However, visual attention data have not been studied alongside tests evaluating biases or social dispositions and may provide additional insight into the perception of those with facial anomalies. The purpose of this study was to evaluate whether interactions between biases and social characteristics with preoperative or postoperative status influence visual attention in laypeople toward those with facial anomalies.

Implicit bias, trait empathic concern, and trait perspective taking interacted with preoperative and postoperative status to influence participants' visual fixations. Participants with higher implicit bias scores spent significantly less visual attention on the cheek and ear preoperatively compared with postoperatively. This finding suggests that people with higher levels of implicit bias avoid looking at anomalous anatomy such as the cheek and ear in HFM, although there was no significant difference for the mandible and chin region. Recent work described positive correlations between IAT scores and activation in the bilateral fusiform gyri and left amygdala when viewing anomalous compared with typical faces, and the left amygdala may link facial perception with moral emotions to guide behavior,[6] which might account for an implicit avoidance behavior as seen here.

In addition, participants with elevated dispositional empathic concern were more likely to spend visual attention on the forehead and orbit preoperatively compared with postoperatively, suggesting participants with higher levels of empathy spend more visual attention on nonanomalous anatomy. Previous work demonstrated that the degree of amygdala signal change in response anomalous faces was inversely related to levels of empathic concern.[6] Participants with higher levels of IRI perspective taking in this study were also significantly more likely to visually fixate on the nose and lips preoperatively. Similar to findings regarding empathic concern, this could suggest that participants with higher levels of perspective taking are more likely to visually fixate on normal anatomy. The reasons for this pattern of gaze distribution are not clear. However, unlike those participants with higher IAT scores, they do not avoid looking at anomalous portions of the face. Although empathic concern and perspective taking were not correlated in this study, previous research has demonstrated significant correlations between these facets of dispositional empathy and other inventories assessing trait empathy.[16,34] This observation could suggest that scores in these dispositions function similarly to influence the visual fixation patterns observed in this study.

Implicit biases and trait empathic concern were linked with amygdala responses to anomalous faces as stimuli in a previous study.[6] These 2 psychological variables also interacted to influence visual attention in this study. The amygdala processes visual signals from the anterior visual cortex via a subcortical pathway from the superior colliculus and thalamic nuclei.[34] The amygdala, then, could be implicated in modulating visual activity by levels of bias and empathy in response to anomalous faces as visual stimuli.[39] Some have suggested that awareness of a negative stimulus is associated with activation of the amygdala to increase activity in the fusiform gyrus, and that this mechanism exists to ensure important visual stimuli achieve awareness.[40]

We acknowledge several limitations in this study. This study used eye-tracking technology with the presentation of stimuli in 2 dimensions. Thus, several anatomic features including jaw projection and lateral mandibular structure may be difficult to discern, and the images may not representative of 3-dimensional human anatomy. This study also presents visual stimuli at fixed distances from the participant, which cannot account for dynamic interactions at different physical distances, as in social settings. In addition, the images used in this study were publicly available, and the details of surgical procedures were unavailable. Finally, several recent critiques of the IAT suggest that the associations it examines are fragile and may not correlate with real-world behaviors. Although potentially flawed, the existence of implicit bias is difficult to deny.

Despite these limitations, this study characterized relations between biases and social dispositions with visual attention toward people with facial anomalies and characterized the way biases and social dispositions influence visual attention when looking at faces with anomalous anatomy.

CONCLUSIONS

Levels of biases, empathic concern, and other social dispositions may influence visual attention toward people with facial anomalies. Those with higher levels of implicit bias may visually avoid looking at anomalous anatomy, whereas those with higher levels of empathic concern and perspective taking do not show similar avoidance behaviors. These findings may have neural underpinnings with amygdala response modulating visual activity in response to facial anomalies. This study has implications for the experience of patients with craniofacial anomalies and for characterizing neurologic mechanisms of the "beauty-is-good" and "anomalous-is-bad" biases.

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