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ORIGINAL INVESTIGATION

How Old Do I Look? Exploring the Facial Cues of Age in a Tasked Eye-Tracking Study

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Abstract

Importance: This is the first eye-tracking study to use a tasked age estimation paradigm to explore the facial cues of age as seen by casual observers.

Objectives: Determine where observers gaze on faces when tasked with estimating an individual's age.

Design, Setting, and Participants: This was a prospective controlled experiment, which took place at an academic tertiary referral center. In total, 220 casual observers (80 untasked, 140 tasked) viewed frontal facial images of women while an infrared eye-tracking monitor recorded their eye movements and fixations in real time.

Main Outcomes and Measures: Multivariate Hotelling's analysis followed by planned posthypothesis testing was used to compare fixation durations for predefined regions of interest, including the central triangle, upper face, midface, lower face, and neck between tasked and untasked observers.

Results: A total of 80 observers (mean age 23.6 years, 53% female) successfully completed the first untasked eye-tracking experiment. A total of 140 observers (mean age 26.1 years, 60% female) successfully completed the second age estimation experiment. On multivariate analysis, there were significant differences in the distribution of attention between observers in the two experiments ($T^2 = 99.70$; $F(5,2084) = 19.9012$, $p < 0.0001$). On planned posthypothesis testing, observers attended significantly more to the lower third of the face (0.20 s, $p < 0.0001$, 95% confidence interval (CI) 0.14–0.27 s) and neck (0.05 s, $p = 0.0074$, 95% CI 0.01–0.08 s) and less to the upper third of the face (−0.27 s, $p < 0.0001$, 95% CI −0.40 to −0.14 s) when tasked. There was no significant difference in time spent on the whole face in the two experiments, suggesting that peripheral elements such as hair color or jewelry did not significantly influence gaze patterns.

Conclusions and Relevance: Humans form judgments about others every day of their lives, and age perception colors their every interaction. To our knowledge, this study is the first to use eye tracking to investigate facial cues of age. The results showed that when tasked with estimating age, casual observer visual attention was shifted toward the lower face when compared with those who were untasked. These data inform our understanding of facial age perception and potential areas to target for facial rejuvenation.

Level of Evidence: NA

Introduction

Perceived age is fundamental to our social interactions. Individuals' apparent age determines how they are treated by society as a result of stereotyped attitudes toward different age groups.[1] In general, those who look younger tend to benefit from stereotypes that favor the young, whereas older individuals are often judged as weak, dependent, and less attractive.[2] In particular, age-related workplace discrimination and its negative impact on mental and overall health are well documented in the literature.[3–7] As the proportion of older workers in the United States labor force continues to increase,[8] understanding the perception of facial age is a timely endeavor.

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KEY POINTS

Question: Where on the face do casual observers look when trying to estimate one's age?

Findings: In this eye-tracking study of 220 total participants, an age estimation task redirected observer attention toward the lower face and neck compared with observers who viewed the same faces without a task.

Meaning: This study allows us to better understand the facial cues of age and will further guide facial rejuvenation procedures.

Social norms are difficult to change.[9] For this reason, older individuals have employed strategies to avoid ageism, including changing their physical appearance.[6] Studies have shown that facial aging is the most important factor in perceived age, which accounts for up to 20% of the variance in the social evaluation of faces.[10,11] It has been suggested that a significant proportion of facial cosmetic surgery patients seek antiaging procedures due to negative societal views about aging.[12] According to the American Society of Plastic Surgeons, >400,000 facelift, forehead lift, neck lift, and blepharoplasty surgeries were performed in 2018.[13] Meanwhile, botulinum toxin type A injections, soft tissue fillers, and chemical peels represented the top three minimally invasive cosmetic procedures that year.[13]

Although there is a general understanding of the physical changes that accompany facial aging, there remains a gap in the literature of how society determines age when looking at an individual's face. The inverted triangle model is frequently used to conceptualize how the face shape changes over time, whereby the youthful downward-pointing triangular shape of the face eventually inverts, becoming wider on the bottom due to upper face volume loss, gravity, and soft tissue laxity.[14] Facial rejuvenation procedures thus target these changes to restore a younger appearance. However, it is unclear where on the face observers look to determine an individual's age. To answer this question, we conducted two eye-tracking experiments—one with and the other without an age estimation task. Because humans glean myriad information from first impressions, including attractiveness, emotion, and trustworthiness, we employed an age estimation task to isolate the clues of facial age.[15,16] The purpose of this study was to better understand the facial cues of age and how an age estimation task redirects observer visual attention. Given the well-documented changes to the lower face and neck with aging,[17] we hypothesized that the lower face and neck would draw greater attention from observers who were tasked with age estimation.

Materials and Methods

Participants

The Johns Hopkins Medicine institutional review board approved this study. Participants capable of normal eye movements were recruited as observers at a large academic medical center. A study surveyor stood at the entrance of the institution's outpatient center, medical education building, and school of public health building. Recruited observers included patients, visitors, staff, and students. Individuals under the age of 18 years as well as those who reported having an affective psychiatric condition such as schizophrenia or autism were excluded from this study due to established differences in the way people with these conditions attend to faces.[18,19] Participant demographics are given in Table 1. Observers were incentivized to participate using a raffle of nominal value, and they were naive with respect to the purpose of the study.

Eye-tracking instrument

Visual scanpaths were recorded with an SMI iView X RED (SensoMotoric, Inc., Needham, MA) eye-movement monitoring system that utilizes a remote infrared camera. The eye tracker is a real-time digital image processor that tracks the center of the observer's pupils and measures their size from an infrared video image of the observer's eyes. Eye position was recorded as x and y values as though the observers were visualizing a grid in the plane of the facial image. Coordinates and pupil diameter were sampled at a rate of 60 Hz.

Table 1. Study participant demographics

	Experiment 1 (untasked), n = *80*	*Experiment 2 (tasked),* n = *140*
Variable	*No. (%)*	*No. (%)*
Age, mean (SD), years	23.8 (1.7)	26.1 (4.4)
Gender		
Female	42 (53)	84 (60)
Male	38 (47)	55 (39)
Nonbinary	—	1 (1.0)
Race		
Asian	35 (42)	57 (41)
African American	3 (4)	10 (7.1)
White	38 (46)	53 (38)
Hispanic or Latino	3 (4)	3 (2.1)
Other	4 (5)	9 (6.4)
Multiracial	—	8 (5.4)
Education		
Less than high school	0 (0)	0 (0)
High school/GED	0 (0)	1 (0.7)
Some college	0 (0)	2 (1.4)
2-year college degree	0 (0)	0 (0)
4-year college degree	73 (91)	104 (74)
Master's degree	5 (6)	21 (15)
Doctoral degree	2 (3)	12 (8.7)

GED, general educational development; SD, standard deviation.

Stimulus material

For this study, 19 color photographs were randomly selected from an aesthetic surgery image archive. All photographs were of female patients who provided informed consent for use of their images in research studies. All photographs were taken in repose as research has shown that smiling influences one's apparent age.[20,21] Photographs were presented in a random order for each participant.

Procedure

Before starting the two experiments, subjects were asked to fill out a brief digital demographics survey. Informed consent was obtained at this time. Subjects were then familiarized with the experiment equipment. They were told that there would be a calibration step in the beginning followed by a series of images of faces. They were instructed to gaze freely upon the faces as though they were sitting across from them in a public setting. In the first experiment (data collection from October 2017 to December 2017), no specific task was assigned for facial viewing. In the second experiment (data collection from December 2018 to January 2019), a different group of participants were told to estimate the ages of the photo subjects and were tasked with typing in their rating of each subject's age using a keyboard. After calibration, each participant examined 10 life-size frontal facial images at a conversational viewing distance of 60 cm. The observer's eye movement recordings were calibrated using a 9-point algorithm. Images were projected on a 17-inch LCD screen at a resolution of 1280 × 1024 pixels for 10 s per image.

Data analysis

The regions of interest, including the eyes, nose, mouth, central triangle as a whole, and the rest of the face, were outlined using SMI BeGaze analysis software (SensoMotoric, Inc., Needham, MA). The upper, middle, and lower face compartments as well as the neck were outlined as described by Leal Silva.[22] Eye movement data were analyzed offline using Hotelling's multivariate *t*-test in Stata 14 SE (Stata Corp., College Station, TX). Because we initially hypothesized that the lower face and neck would draw greater attention in the tasked group, one-tailed *t*-tests were specifically performed for these two regions in planned posthypothesis testing. Bonferroni's correction was applied to the major hypotheses of this study (comparing time spent on the central triangle, the three thirds of the face, and the neck, between groups), and the alpha value was adjusted to $p = 0.01$. Demographics information was collected using Qualtrics Survey Software (Qualtrics, Provo, UT).

Results

Eighty observers (mean age 23.6 years, 41 females) successfully completed the first untasked eye-tracking experiment. In total, 140 observers (mean age 26.1 years, 84 females) successfully completed the second tasked eye-tracking experiment. Mean fixation times for the primary areas of interest are given in Table 2. Hotelling's multivariate *t*-test revealed significant differences in the distribution of attention on faces between tasked and untasked observers ($T^2 = 99.70$; $F(5,2084) = 19.9012$, $p < 0.0001$). On planned posthypothesis testing, we found that observers attended significantly more to the lower third of the face (0.20 s, $p < 0.0001$, 95% confidence interval [CI] 0.14–0.27 s) and neck (0.05 s, $p = 0.0074$, 95% CI 0.01–0.08 s) while spending less time on the upper third of the face (−0.27 s, $p < 0.0001$, 95% CI −0.40 to −0.14 s) when told to estimate the photo subject's age. Meanwhile, there was no significant difference in time spent on the midface ($p = 0.90$).

Although the majority of attention was directed toward the central triangle (eyes, nose, and mouth) in both the untasked and age estimation studies relative to the remainder of the face, the total time spent on the central triangle differed between the two studies (0.78 s less in the tasked group, $p < 0.0001$, 95% CI 0.59–0.97 s). Conversely, observers tasked with guessing the subject's age spent significantly more time on the peripheral face outside of the central triangle (0.72 s, $p < 0.0001$, 95% CI 0.52–0.92 s). Table 3 summarizes these findings. Furthermore, two-sample *t*-test indicated that the total amount of time that participants spent on the whole face did not differ significantly between the tasked and untasked experiments ($t(2,088) = 0.64$, $p = 0.5217$). Overall, casual observers tasked with age estimation redirected their attention away from the upper region of the face and gazed longer at the lower face and neck. Figure 1 represents heat maps of observer visual attention in both experiments.

Although not a major objective of our study, we also wanted to investigate whether attention inside the

Table 2. Mean fixation times across regions of interest

	Mean (SD), ms		
Region of interest	*Untasked*	*Tasked*	*No./group*
Eyes	3360 (2302)	2477 (1811)	760/1330
Nose	1686 (1551)	1537 (1200)	760/1330
Mouth	470 (728)	724 (826)	760/1330
Central triangle	5516 (2360)	4739 (1964)	760/1330
Remainder of face	450 (85)	1172 (58)	760/1330
Upper face	1339 (1620)	1068 (1364)	760/1330
Midface	4204 (2558)	4216 (2013)	760/1330
Lower face	423 (684)	626 (762)	760/1330
Neck	128 (399)	173 (414)	760/1330

No./group, number of observations per group untasked/tasked.

Table 3. Post hoc comparison of tasked and untasked experiments

Region of interest	*Mean difference,[a] ms*	*95% CI*	p[b]
Eyes	−883	−1062 to −704	<0.0001
Nose	−149	−268 to −29	<0.0001
Mouth	255	184 to 326	<0.0001
Central triangle	−777	−965 to −588	<0.0001
Remainder of face	721	521 to 922	<0.0001
Upper face	−270	−401 to −140	<0.0001
Midface	12	−211 to 186	0.90
Lower face	203	138 to 269	<0.0001
Neck	45	9 to 82	0.0074

[a]Mean difference = mean fixation times in tasked minus untasked groups.
[b]Significant if $p < 0.01$.
CI, confidence interval.

central triangle was redistributed in the tasked group. Multivariate analysis revealed differences between the two groups ($T^2 = 143.89$; $F(3,2086) = 47.9184$, $p < 0.0001$). Specifically, observer attention was directed away from the eyes (−0.88 s, $p < 0.0001$, 95% CI −1.06 to −0.70 s) and nose (−0.15 s, $p < 0.0001$, 95% CI −0.27 to −0.03 s) toward the mouth (0.26 s, $p < 0.0001$, 95% CI 0.18–0.33 s), indicating a downward shift of visual attention within the central triangle as well. Finally, it is conceivable that one may spend more time looking at an older individual's neck. However, there was no obvious linear relationship between the time spent looking at the neck and the photo subject's age as rated by the observer (Pearson's correlation coefficient = −0.0086).

Discussion

The desire for everlasting youth has created and sustained a multibillion-dollar industry. In 2017, the global antiaging market was valued at >$165 billion and is expected to continue growing.[23] Although there are various reasons why people wish to appear younger, a common theme is the social penalty that comes with aging.[3] One notable example is employment opportunity. Workplace discrimination against older adults is frequently cited in the literature. This can come in the form of overt discrimination, such as lower pay or employer refusal to hire, which is illegal but difficult to prove.[24] More commonly, older workers experience ''soft'' forms of discrimination—for example, lack of respect from coworkers and teasing.[24] Therefore, it is unsurprising that people have become proactive in avoiding ageism, including physically concealing their age.[6]

A considerable amount of work has gone into characterizing the physical signs of facial aging. From extracting age-related patterns using complex statistical modeling to averaging young and old faces together to investigate differences, researchers have long sought the key features that determine the age of a face.[25] Fink et al. demonstrated that although the skin on the body may influence one's apparent age, the face is the most significant aspect in age perception.[26] Numerous models of age-related facial changes have been proposed, many of which converge on the morphological evolution of the face over time.[27] However, few studies to date have explored the salient facial features involved in age estimation from the perspective of society.[28,29] To our knowledge, this study is the first to use eye-tracking technology to determine where observers look when tasked with assessing an individual's age. Gaze patterns are a robust measure of visual attention due to the conserved nature of facial processing in humans.[30,31] We employed an age estimation task to identify facial regions, as well as the neck, on which casual observers attended for age-related cues.

Our results showed that tasking observers with age estimation redistributed visual attention on faces in frontal view. Compared with untasked observers, those who were asked to assess age directed their attention away from the

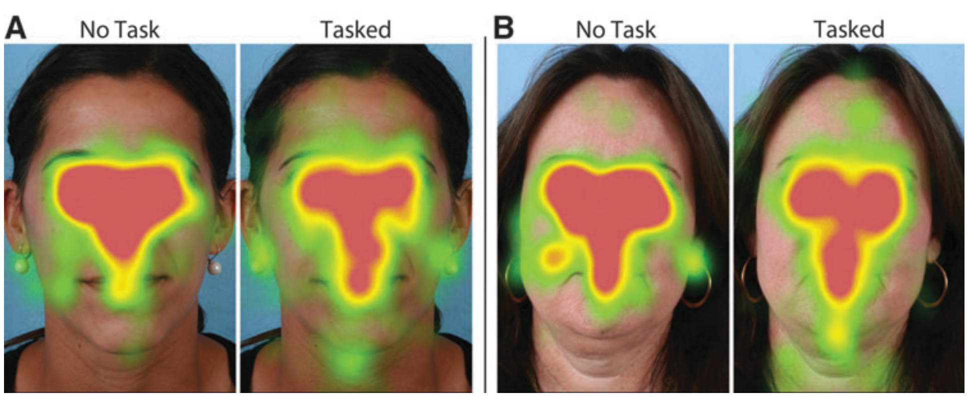

Fig. 1. Two examples of visual attention heat maps **(A, B)**. When tasked, attention is redistributed down to the bottom third of the face, particularly over the mouth. Heat map: red>yellow>green>no color (least time spent).

upper third of the face and gazed significantly longer at the lower third of the face and neck. This finding aligns with several theories regarding facial aging that describe progressive downward displacement and overall volumetric remodeling of soft tissue facial compartments. In addition, Imai and Okami recently demonstrated that the impression of swelling at the bottom of the face was the largest contributor to age perception using three-dimensional head and face forms and principal component analysis.[25] Of note, the total amount of time spent on the face itself was not significantly different between the two experiments, meaning that study participants reallocated their visual attention within the face rather than to outside elements (e.g., hair color or jewelry) when trying to determine one's age. Furthermore, we initially hypothesized that observers would spend significantly more time on the lower face and neck for older subjects based on the idea that signs of aging in these areas would draw the eye. However, observer visual gaze patterns were not significantly associated with their ratings of perceived age. This finding may suggest that tasked observers searched the lower face and neck for signs of aging (e.g., jowling and perioral wrinkling), and their presence or absence clued them in to the age of the person.

Although the total duration in which tasked observers gazed upon the neck was statistically significantly longer than their untasked counterparts (0.05 s), the magnitude was smaller than expected given the recognized importance of neck appearance on the youthfulness of a face.[32,33] One explanation is the limited presentation of stimuli in a two-dimensional frontal plane. Topographical patterns of neck aging may have been more difficult to appreciate due to the lack of depth in two-dimensional photographs as opposed to those taken at an oblique or lateral view. Likewise, facial perception studies have recently begun to employ three-dimensional stimuli to better approximate realistic social encounters.[25,34] Alternatively, casual observers may only need an extra fraction of a second to incorporate neck rhytids into their assessment of one's age. These considerations will be important in future research.

A second objective of our study was to explore any differences in the time spent on the central triangle as a collective (eyes, nose, and mouth) between the two experiments. Tasked observers spent $\sim$770 ms less on the central triangle on average in favor of the remainder of the face. Heat maps further confirm this finding (Fig. 1). Moreover, attention appeared to be redistributed inside the central triangle. Significantly less time was spent gazing on the eyes and nose in favor of the mouth, implying the importance of the latter region in estimating age. Characteristics that define ''mature lips'' include volume loss, perioral rhytids, philtrum flattening, and down-turning oral commissures.[35] Recent studies have also begun to highlight the role of the lower central face (upper and lower lips, chin) in one's apparent age.[36,37] To be clear, these results do not mean that the eyes are less significant in determining facial age. On the contrary, the time spent on the eyes still constituted a relative majority as compared with the nose or mouth. Taken together, these findings highlight the integral part that the lower face—particularly the mouth—plays in apparent facial age.

Overall, the findings in this study align with current facial rejuvenation techniques, the cornerstone of which is facelift surgery with fat grafting and injectable fillers serving as adjuncts.[38–40] The downward shift of visual attention in tasked observers implies a tendency to look for facial cues of aging in the lower face, notably on the mouth, that can be targeted with these procedures. Perhaps the mouth and central lower face deserve more attention in facial rejuvenation as Fedok suggests.[36] Alas, one must also consider facial age from different perspectives. Our study participants viewed faces in frontal plane at a conversational distance of 60 cm, allowing them to see salient facial features in detail. As Lam notes,[14] ''an onlooker can oftentimes tell the age of an individual from across the room… [because of] overall facial shape.'' It is possible that, from afar, prominent peripheral structures such as jowls have a greater influence on one's apparent age. This hypothesis should be tested in future investigations.

There are several limitations to this study. First, our findings are limited in generalizability given that our stimuli comprised photographs of women only. Some have reported on gender differences in age-related information in the face[25]; thus, it will be important for future studies to explore the facial cues of age in men. Nevertheless, this study has broad impact given that women comprised >90% of all cosmetic procedures done in 2017.[41] In addition, it has been reported that women experience higher rates of ageism than men due to problematic and negative stereotypes in society.[24,42] A second limitation of our study is the limited presentation of stimuli. All photographs were shown in two-dimensional plane and frontal view. As previously discussed, this study may not have captured the true effect of features that are viewed more easily with depth (three dimensions), from a different view (lateral or oblique), or both. Finally, total fixation times were measured in predefined compartments as described by Leal Silva[22] rather than by specific areas. This approach had the potential to obscure some of the findings localized to the midface region. Although the total time spent in the midface compartment did not differ between the tasked and untasked observers, the heat map analyses suggest that attention was concentrated more centrally (e.g., over part of the nasojugal and nasolabial folds) in the tasked group. Future eye-tracking studies should be more granular when delineating regions of interest before analysis. Despite these limitations, this study contributes to the understanding of facial cues of age in women from the perspective of society using eye-tracking technology. Our findings may inform conversations with patients regarding facial age perception as well as areas to target for facial rejuvenation procedures. They also lay the foundation for future research involving visual gaze patterns as they relate to age perception.

Conclusions

Humans form judgments about others based on daily observations, and age perception colors their every interaction. To our knowledge, this study is the first to use eye tracking to investigate facial cues of age. The results showed that when tasked with estimating age, casual observer visual attention shifted downward to encompass more of the lower face when compared with those who were untasked. These data add to our understanding of facial age perception.

Author Disclosure Statement

No competing financial interests exist.

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